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PROCEEDINGS
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GEOLOGISTS' ASSOCIATION.

VOLUME THE FIFTEENTH,
1897-1898.

EDITED BY
H. A. ALLEN, F.G.S.



*(Authors alone are responsible for the opinions and facts stated in
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ADDENDA ET CORRIGENDA.



- Page 3, line 7, *for* "†" *read* "‡."
 3, line 8, *for* "‡" *read* "†."
 21, line 22, *for* "Whittaker" *read* "Whitaker."
 27, line 5, *for* "Cœnosphæra" *read* "Cenosphæra."
 27, line 21, „ "Cœnosphæra" „ "Conosphæra."
 „ 28, line 16, „ "Cœnosphæra" „ "Cenosphæra."
 „ 29, line 1, „ "Cœnosphæra" „ "Cenosphæra."
 „ 62, line 10 from foot, *for* "Colonel" *read* "Captain."
 „ 89, line 12 from foot, *for* "Lima spinosa" *read* "Spondylus spinosus."
 „ 129, line 23, *after* "p." *add* "259."
 „ 129, line 5 from foot, *for* "Anthnoy's" *read* "Anthony's."
 „ 144, line 15, *for* "Caliopristodus" *read* "Callopristodus."
 Plate VII, *for* "To face p. 174" *read* "To face p. 157."
 Page 189, line 4, *for* "T. R. Johnson" *read* "Wheeler."
 Plate IX, *for* "To face p. 211" *read* "To face p. 222."
 Page 373, bottom line, *for* "but, as Murchison had suggested" *read* "as Murchison had suggested, but."



INSTRUCTIONS FOR BINDING VOL. XV OF THE "PROCEEDINGS."

Plates I and II should face p. 52	Plate IX . should face p. 222
Plate III . " " 38	" X . " " 340
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PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

AN OUTLINE OF THE PETROLOGY AND PHYSICAL HISTORY OF THE ALPS.

By PROF. T. G. BONNEY, D.Sc., LL.D., F.R.S.

[Read January 1st, 1897.]

THE meeting of the International Geological Congress at Zurich, in 1894, was followed by excursions in which some of your members took part, and of which reports were read at one of your meetings and printed in your PROCEEDINGS.* Such reports, though often interesting and valuable (as these were), are, however, sometimes little more than the echo of the opinion of the leaders of the party, because the writers of them have hardly the opportunity of forming an independent judgment. Thus I noted once or twice, more especially in one of them, statements which I knew to be disputable, if not dubious; and it occurred to me that a synoptic view of the geology of the Alps, as I understand it, might be of some interest to your members. In dealing with matters of controversy I shall not, as a rule, enter into details, but content myself with referring to papers in which these are fully discussed.

If I cite but seldom the writings of others, it is not because these are ignored, but because my statements are the results of personal experience. In regard to that, I believe no English geologist, and probably not many foreigners, have seen so much of the Alps as myself. I do not, of course, pretend to have worked up the geology of special districts with the same minuteness as those who have executed the surveys or have written monographs, but I have compared district with district in a way which not many have had the opportunity of doing. Altogether I find that I have made twenty-seven journeys in the Alps since 1856, when for the first time I set my foot on a glacier. This means that I have spent over two years of my life among their peaks and valleys.

* Vol. xiv, p. 40.

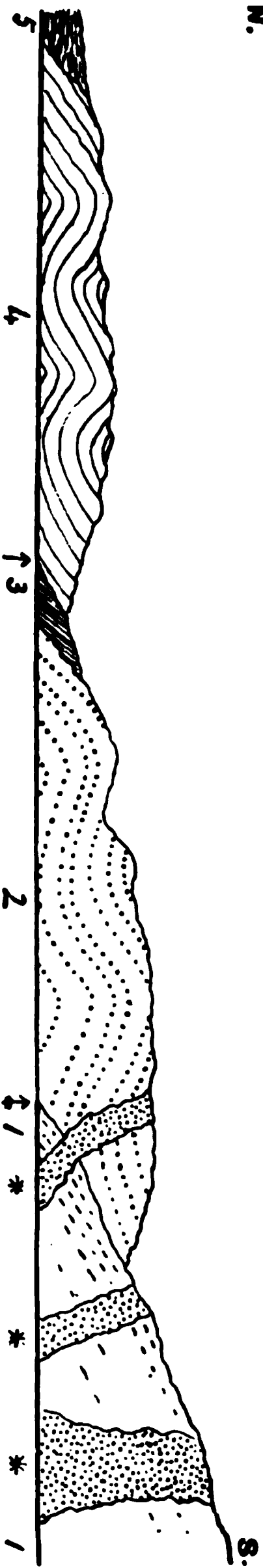
Questions connected with ice work at first chiefly engaged my attention ; but about twenty-five years ago I began to look more narrowly at the rocks, and since 1880 have been gradually drawn into the study of the gneisses and schists as distinguished from the more massive crystallines. The last seven or eight journeys have been planned with the view of testing sundry controversial questions, so that if I express in this paper any opinion which does not accord with what has been published by some continental geologists of repute, you may assume that it is the result of personal independent work.

The Alps are composed of two great groups of rocks, crystalline and ordinary sedimentary, folded and faulted * together, which groups, except in a very few cases to be noticed later, are perfectly distinct and not difficult to distinguish. Fig. 1 shows their general relations. From the sedimentary group, igneous rocks, whether contemporaneous or intrusive, are generally absent ; though in one region they are abundant among its basal members, and occur locally elsewhere, though usually at a much higher horizon. The members of the crystalline group are granites, diorites, and allied holo-crystalline rocks, a large variety of gneisses and schists, some peridotites (commonly in the condition of serpentines), gabbros, diabases with kindred basic rocks, and some felstones. The great majority of these are older than any of the sedimentaries. The members of the latter group are sandstones, mudstones, and limestones, which, of course, graduate one into the other. The sandstones are the less common, and breccias or conglomerates, except in two instances of rather late date, are comparatively rare ; the mudstones take the form of shales or slates, frequently the latter ; the limestones may be magnesian, and in one district dolomite is abundant. Both crystalline and sedimentary rocks throughout the chain are usually much affected by pressure, and it may be well, before proceeding further, to give a brief outline of its effect.

First in regard to the crystalline rocks. Pressure crushes the constituents, especially when the rock is coarse-grained, and it leads (how far directly cannot easily be determined) to mineral changes. It may produce either simple crushing, such as would be effected in a Brahmah press, or a shearing crush. Commonly, I think, though not always, the fragments of the rock undergo some lateral displacement, in other words it is more or less sheared. I need hardly mention the effects of pressure on the sedimentaries, for they are those with which every geologist is familiar. It is not unusual in examining these to find that among the argillaceous rocks, more or less micro-mineralogical change has occurred, so that a phyllite rather than a slate is the result.

* I may say, once for all, that, while the importance of folding has been fully appreciated by continental workers in the Alps, that of faulting, and especially of thrust faulting, has been sometimes overlooked. I think that some of the more anomalous cases of folding would be much more simply explained by appealing also to the effects of overthrust faults ; and I am strongly of opinion that in some parts of the Alps the rock masses are almost " sliced up " with faults.

N.



DIAGRAMMATIC SECTION OF ALPS FROM THE SWISS LOWLAND TO THE WATERSHED OF THE CENTRAL ALPS.

1. Complex of crystallines, generally rather coarse, sometimes closely resembling the Laurentian type of rocks, often assuming in upper part a more stratified aspect.
 2. Crystalline schists, to a large extent metamorphosed sedimentaries.
 3. Palæozoic rocks (generally Carboniferous, possibly sometimes older) : not always present.
 4. Mesozoic and early Kainozoic rocks. The Trias variable in thickness, sometimes absent.
 5. Oligocene and Miocene (Nagelfluh, Molasse, etc.)
- * Intrusive granites, etc.—probably for the most part Pre-Palæozoic.
- † Here in some regions come schists and gneisses of Lepontine type, apparently linking together (1) and (2).
- ‡ Here Permian (generally igneous in origin) sometimes comes between 3 and 4.
- * * It must be distinctly understood that this section is diagrammatic and composite. It does not represent exactly any one part of the Alps, but is intended to represent the author's interpretation of the field evidence over a large area of the more central part of the chain.

Moreover, instances of the coincidence of cleavage and bedding are rather common.

The mineral changes are, however, more marked among the holo-crystalline than among the sedimentary rocks. Let us take, as an example, the case of a granite which has been exposed to severe pressure. The quartz shows the effects of strain, and cracks up, the felspar is crushed; the mica becomes bent or tattered. The crushed felspar very commonly undergoes separation into quartz and a potash or a soda mica, so that in some cases the original mineral almost disappears from the rock. Thus a mica schist may be produced, as a result of crushing, from a granite; for a rude cleavage is formed and the surfaces of this are coated with a minute silvery mica.*

Thus, when the pressure has been less severe, a fragment, if the flat surface be regarded, may seem to be a mica-schist, but if it is looked at edgewise, a gneiss. This has been the foundation of the statements, once so common in geological books, about granite passing into gneiss, and gneiss into mica-schist. The fact was really, that a mica-schist was manufactured from a gneiss, and a gneiss from a granite.†

The history of an augen-gneiss is such as I have just described. The felspars are rounded by having their corners crushed off, and it is possible to trace every change, from a porphyritic granite to an irregularly-streaked, almost laminated, gneiss.‡ But I doubt whether truly banded gneisses—I mean those where the rock exhibits distinct layers (say from a quarter of an inch thick upwards, and many inches in length) varying markedly in their mineral constituents—can be formed by any kind of crushing from an ordinary holo-crystalline rock, however coarse. These structures, which may be also seen in dioritic rocks and gabbros, are due, in my opinion, to fluxion movements in the rock after some mineral differentiation had occurred, but anterior to final consolidation.§ Banded gneisses may be formed by what has been termed "*lit par lit injection*," but such cases are, I believe, very rare. Others again may have been originally sedimentary rocks, which have been subsequently altered, but these certainly are very much less common than was formerly supposed; indeed I cannot cite a single instance of any considerable mass of gneiss to which I am certain this origin must be assigned. Of the great majority we may say with confidence that they are granites or nearly related igneous rocks, in which the foliated structure sometimes is original, but often has been subsequently impressed during earth movements. The same is true of the dioritic rocks. Here also we have hornblende-schists, both those which are simply foliated, and those that are also

* For these I have proposed the name of Sheen-surfaces. On this subject see Presidl. Address, *Quart. Journ. Geol. Soc.*, vol. xlii (1886); *Proc.* pp. 94-99.

† I do not, however, mean to assert that all gneisses and all mica-schists have this origin.

‡ *Geol. Mag.*, 1894, p. 114.

§ *Quart. Journ. Geol. Soc.*, vol. xlvii (1891), pp. 483, etc.; xlviii (1892), pp. 128, etc.: lii (1896), pp. 40 etc.

banded. The former usually result from pressure; the latter acquired their structure in cooling; though, of course, they may have been afterwards modified by pressure. In many cases the pyroxenic mineral originally was augite, and the rock a dolerite or basalt. That, no doubt, is the history of many of the green schists, which, as will be noticed later on, play an important part in the geology of the Alps. When the foliated structure is a consequence of pressure, the hornblende, so far as I have observed, always takes an acicular, or at any rate a long prismatic, form.* An actinolitic habit may be assumed, it is true, without any special action of pressure, as sometimes happens when a gabbro becomes hornblendic and the outside of the original grain of augite is fringed with a growth of pale green actinolite, like blades of grass, but this change is local and partial, and, so far as my experience goes, can be readily distinguished. To this subject, however, I shall have to refer later on. True peridotites occur in Piedmont towards the margin of the Alpine chain, and in one or two localities in the Tyrol, but I have not had the opportunity of visiting any of these. Serpentine, in which olivine still remains, are not, so far as my knowledge goes, very common; though, it is evident, to the experienced eye, that this mineral has once been an important, if not a dominant, constituent. Two types appear to occur in the Alps; one is a bastite-serpentine with accessory augite; the other seems to be rich in augite, with little or no bastite; the latter serpentine being generally a rather harder and tougher rock than the former and a little rougher to the touch. But I am not yet in a position to affirm that they indicate distinct effusions. They may be merely portions of a magma, which had already undergone some differentiation. The usual colour of both rocks is a dark green, any approach to redness being very rare. In fact the former group of serpentines (the altered saxonites) are very like those which are found in the vicinity of Genoa.† The Alpine serpentines often are greatly crushed, sometimes so much so as to resemble a slate.‡ Sometimes these become converted locally into a true talc-schist. Gabbro is not rare in the Alps; the largest mass known to me is that of the Mont Colon, near Arolla. The felspar commonly is converted into the dead-white mineral which passes under the name of saussurite; the diallage into some form of hornblende.§ Occasionally such a gabbro shows signs of pressure-modification, but I think that this, as a rule, is not the primary cause of the mineral change, for the rock appears to be very intractable. In some instances it cuts the serpentine, a common and well-known relation. Conspicuous smaragdite distinguishes a variety which

* *Quart. Journ. Geol. Soc.*, vol. xlix (1893), p. 94; vol. l. (1894), p. 279.

† *Geol. Mag.*, 1879, p. 362; 1880, p. 538.

‡ "As, for instance, at the head of the valley of the Guil, near the Viso, and in places on the Gorner Grat, near Zermatt." *Geol. Mag.*, 1890, p. 533.

§ In the unaltered rocks olivine is generally present, but we lose the traces of this (as at the Lizard) in the process of mineral change.

crops out on the Allalin Glacier, and boulders of it may be traced at least as far as Geneva. In it glaucophane sometimes occurs, and garnets are not very infrequent.*

It would not, indeed, be correct to affirm that these holocrystalline, mostly granitoid, rocks are always the oldest in the Alps,† for their age in many cases is a matter of inference rather than of proof. Still, not seldom their antiquity can be demonstrated; hence, though, in the Alps as elsewhere, igneous rocks of uncertain age may form part of the complex, we may confidently claim a great mass of rocks not only as Archæan, but also as representing a rather early part of this era. In some districts a second group of rocks occurs, apparently higher in position than the last-named, and consisting mainly of fairly massive mica-schists rich in biotite; these sometimes are gneissoid, and they often contain rather large red garnets and long crystals of actinolite. This group, as was pointed out by Dr. Sterry Hunt, presents certain rather distinctive characteristics, such as a saccharoidal texture in the more felspathic kinds, an abundance of a silvery mica and of red garnets in the more schistose, the occasional presence in the latter of such silicates as kyanite and staurolite (which, however, also occur in a higher series), and the like. Dr. Hunt proposed to give the name Montalban to this group (from the White Mountains in North America), and to assign it a chronological value. In the Alps, so far as our knowledge at present goes, this appears, when it occurs, to occupy a fairly definite horizon, and to form a kind of transition between the coarsely crystalline gneissoid rocks, already mentioned, and the group of schists, of which I am going to speak. But it is perhaps safer, in the present state of our knowledge, to use the term Montalban in a petrological rather than in a chronological sense.‡ These rocks are now truly metamorphic; but which of them were originally igneous, and which, if any, were sedimentary, we are not yet in a position to determine. It is, however, my impression that the group will be found ultimately to form a definite part of the Alpine succession.

We come next to a group of which we can speak with more confidence, both as to its position and the origin of most of its members—that of the “Upper Schists” as I have generally designated it.§ This consists largely of rocks which were once true sediments, though now they are no less truly crystalline. It can be traced, to my knowledge, along the whole chain of the Alps from the Viso to beyond the Gross Glockner. I have no

* *Phil. Mag.*, 1892, p. 237.

† The protogine of Mt. Blanc is not the oldest part of the mountain mass, for it can be seen to be intrusive in other crystallines and in several other places I have found a porphyritic granite intrusive in gneissoid rocks and schists. The Tonalite of the Adamello also is intrusive in the “Upper Schists.”

‡ I have often referred to them as the Lepontine group, since they are exceptionally well developed in the Lepontine Alps, near the St. Gothard Pass.

§ Described in papers in *Quart. Journ. Geol. Soc.* for 1889, 1890, 1893, 1896.

doubt of its occurrence well to the south of the one and to the east of the other, but, as it happens, no member of it is found in such districts as I have examined. Restricting ourselves for a moment to those members which must have once been sediments, we may say that they present us with three extreme types : a more or less schistose marble (sometimes dolomitic), a mica-schist, and a quartz-schist. The group also contains some green schists, which I pass over for the moment, and some few rocks indubitably intrusive, such as granite (generally porphyritic), and serpentine. The above-named three types represent respectively ancient limestones, mudstones, and sandstones. Of this, I think, no one who has studied them in the field can entertain any doubt. Just as in the case of ordinary sedimentary strata, such, for instance, as the Mesozoic rocks of the Alps, we find every possible gradation and all sorts of variations in mineral character, from the alternation of masses to that of mere bands, so do we with this group of schists. Mica is not often, and calcite but seldom, entirely absent. Still we can now and then find a quartz-schist almost free from both minerals, containing only a few spangles of white-mica here and there, or a marble which practically is free from quartz or even from mica ; but the one rock will graduate either into a quartz-schist, very distinctly banded with mica, or into an ordinary quartzose mica-schist ; the other into a marble with micaceous bands, or into an ordinary calc-mica-schist. Microscopic study of the quartz-schists shows that their structure—*i.e.*, the form of the constituent quartz grains—differs very markedly from that of an ordinary quartzite, and that this difference does not seem adequately explained by the action of pressure after partial metamorphism. Still, that we are dealing with a rock originally clastic cannot be doubted, for in certain localities bands of pebbles may still be detected in the coarser varieties of this quartz-schist.* Among the mica-schists, one of the most marked and widely extended types consists largely of mica, both brown and white, the latter being generally small and, in some cases, a secondary product. This rock is always dark in colour, often almost black ; apparently owing to the presence of iron-oxide and some graphite. In certain districts it is characterised by the abundance of a garnet, generally darkened by impurities, but occasionally of a dull reddish colour, which varies in size from that of a wild cherry downward. It belongs, I believe, like the garnets in the “Montalban” group, to the almandine section ; but, as Dr. Grubenmann states,† a satisfactory analysis cannot be obtained owing to the abundance of adventitious matter. Staurolite sometimes occurs associated with this garnet, and the former mineral is large and abundant in a schist which, in the Val Piora, enters into the same group ; rutile also is

* *Geol. Mag.*, 1893, p. 204 ; 1896, p. 400.

† Analysis quoted in *Quart. Journ. Geol. Soc.* (1890), xlii, p. 225.

a rather common constituent. This dark schist sometimes occurs in masses of considerable thickness; occasionally it is interbanded with an impure quartz schist; the two forming layers which vary in depth from several inches to hardly more than lines.* The dark schist is commonly a little calcareous, and it passes in some localities, either gradually or rapidly, into a white or cream-coloured marble or dolomite. In this, at one locality, large crystals of tremolite are abundant. Another member of the group is a disthene schist, or, more strictly speaking, a schist chiefly composed of two species of mica, with disthenes (or kyanites) generally very small in size. All the members of this group of schists have been modified by pressure, which acted after they had assumed a crystalline condition. Sometimes they are wonderfully puckered and contorted; they frequently exhibit sheen-surfaces, and occasionally strain-slip cleavage; sometimes the crushing and shearing has been so great that they have become quite slaty. The garnets also are often distorted and cracked, occasionally even "sliced"; and the staurolites have suffered, though on the whole not so much. The pressure, as already said, has produced sheen-surfaces in the mica-schists; it has sometimes made the quartz-schists so "slabby" that they can be used for paving, or even for roofing, and it has occasionally left its mark on the marbles or dolomites, which also are not seldom so affected by crushing as either to become rather friable or to assume a much more compact structure than properly belongs to them. But a little careful study shows that the pressure has acted upon a rock already crystalline, and that, besides this, in those cases where locally a crushed mica-schist is hardly distinguishable from a phyllite, or a marble from an ordinary pure limestone (such as may be found sometimes in the Alpine Mesozoic rocks), pressure has not so much been the cause, as it has undone the work of crystallization; in other words, it is not so much a fragmental rock which has been made crystalline, as a crystalline rock which has been reduced to a fragmental condition. These changes also—these difficulties as to the true nature of the rock—are only local, and but rarely cause serious perplexity. As a rule three things are clear in regard to this group of schists, considered as a whole: (*a*) that its members were originally sediments; (*b*) that they afterwards assumed a crystalline condition, so that in almost every case the original structures were obliterated by mineral changes; and (*c*) that if these changes were due to pressure, this was very far from being the only agent, though it has undoubtedly produced effects, sometimes very marked, since the rock became crystalline.

Before quitting this group we must notice the green schists (*Grüner Schiefer* of the Swiss geologists), which often seem to

* This interbanding is remarkably well exhibited in the Lepontine Alps, especially at various localities between the Binnenthal and the Val Greina.

form an integral part of it. These are hornblendic and chloritic schists, containing more or less epidote, felspar (this, or some kindred silicate, being often of secondary origin), micas, garnet, and quartz, with sundry other constituents of minor importance. Glaucophane also is occasionally present. In the coarser varieties the individual minerals (excepting the garnets, which sometimes run rather larger) are not often more than $\cdot 1$ inch in diameter, and from this they become more and more minute, till the schist, at first sight, might be taken for a green slate. Occasionally the rock exhibits a mineral banding, but very often it is uniform. Obviously, like the schists with which it is associated, it has been modified by pressure in one or more of the later stages of its history. It is difficult to ascertain with certainty the origin of this green schist, or, indeed, whether there may not be more than one. We sometimes obtain distinct proof that it is intrusive in the calc-mica schists; in a single case only have I suspected a passage from the one to the other; in many instances no definite evidence is afforded.* The green schist is not always present; not seldom, however, there may be more than one mass of it. The outcrops vary in form, being sometimes rather irregular; but sometimes they are like sills or interstratified beds. They appear not to belong to any definite horizon, though I think that as a rule they occur in the lower part of the calc-mica schist. We meet with a similar rock among the gneisses, but here there can be no doubt that it is intrusive. In my opinion, and I have paid some attention to the subject, these green schists usually represent a group of intrusive diabases, modified by pressure and other agents of alteration,† though, at present, I would not exclude the possibility of some basic tuffs being locally present. In other words, I think they were not deep-seated intrusions, so that I should not be surprised if they passed locally into surface eruptions. I have already stated that a belt (speaking in general terms) of rather similar rocks occurs among the gneisses on the south side of the watershed of the Alps. With these I am less familiar, for it is many years since I saw them; but, so far as I remember, they usually are rather more coarsely crystalline than those just described. Possibly they may be a set of approximately contemporaneous intrusions, but more deeply seated. For these Dr. Sterry Hunt proposed the name of the *Pietra Verde* group, regarding it as having a chronological value. So far as I understand him, he considered these and the green schists associated with the calc-mica schists to be on the same geological horizon. I must say that, in my opinion, a more intimate knowledge of the Alps would have shown him that not only is it impossible to arrive

* Junctions in the Alps have an exasperating habit of becoming masked by *débris* turf, etc.

† *Quart. Journ. Geol. Soc.*, vol. I (1894), p. 279.

at any very definite conclusion as to the age of these green schists, but also that the correlation of them with the Huronian of North America is in the highest degree improbable. The latter (excluding intrusive igneous masses) are sedimentary rocks, often only little altered ; but there is not a single member of the green schists (so far as I have seen them) to which one can with certainty attribute a clastic origin ; and if such an origin could be established, then their alteration is very great.

The serpentine is generally, but not invariably, associated with the green schist. Even where direct evidence of its relations is wanting, the outline of the outcrop usually suggests intrusion. When we remember that the Appenine serpentine is of late date, and often resembles that of the Alps, we are tempted to wonder whether the latter also was extruded in Tertiary ages. But except in one case, near Matrei, on the Brenner, where the evidence was very far from clear, I have never seen it intrusive in any rock which did not belong to the crystalline series. Indeed, as I have already said, intrusive igneous rocks, as a rule, rarely occur among the sedimentaries of which the geological horizon can be determined. There are, indeed, certain granites associated with the crystalline schists and gneisses, such as those in the Gasterenthal, in the Engadine, near Baveno, etc., which the Swiss geologists are disposed to refer to the Permian period, and they seem really separable from the granitoid rocks which ordinarily form part of the crystalline "complex"; in the latter also we find locally "porphyroids" which may be of the same date, but, so far as I know, there is no evidence in regard to either which can be called conclusive. The great Alpine locality for igneous rocks of Permian and Triassic age, as every geologist knows, is the southern Tyrol, on either side of the Adige, in the district of which Predazzo may be regarded as the centre. Of these, as it is classic ground, I need not give any description. Masses of "porphyry," doubtless belonging to the same period, may be traced at intervals on the south side of the chain westward, to beyond the Lake of Orta ; and some rather similar rocks are found in other parts of Switzerland (as on the Windgelle, and in the mountains not far from Vernayaz), which are approximately contemporaneous. In the remainder of the Mesozoic era, and in the earlier part of the Tertiary, the region of the Alps appears to have been singularly free from eruptive action ; and even the great successive earth movements, which produced the present chain, seem to have been seldom associated with volcanic discharges. There are exceptions, however, as in the case of the "Alpine melaphyr" of Allgäu, the so-called Taveyanaz sandstone and the basalts of the Vicentin Alps, but I have not examined any of these in the field.

We come next to deposits the age of which can be determined by fossils. On the north-eastern margin of the chain strata occur which have been referred to the Silurian and the

Devonian periods. These I have seen only in one place, and then but in passing, near Kitzbühel. They were greywackes and slaty argillites, which had derived some of their material, at any rate, from crystalline rocks. The Carboniferous system is represented in the Alps by certain fossiliferous limestones and other deposits in the Guilthal district (which I have not seen) and by a number of strips, commonly restricted in breadth and sharply infolded, which may be traced at intervals all through the Central and Western Alps. In these infolds conglomerates and breccias are not rare, though black slaty rocks, passing into phyllites, are more common, which are sometimes good enough to be quarried. Small beds of anthracite occur occasionally, and fossil plants are abundant in one or two localities, perhaps the most noted being in the glen of the Dioza near the Col d'Anterne.* In the upper valley of the Rhone, at no great distance from the river, are some dark schistose rocks which present a more modern aspect than any of the "Upper Schist" group described above, and may possibly belong to the Carboniferous system, and with them I am disposed to group the so-called Pontiskalk which crosses the entrance of the Val d'Anniviers.† Occasionally it is far from easy to distinguish these schistose rocks from members of the crystalline group. The difficulty, however, is only local, and is due to the fact that these later rocks are sometimes composed of materials obtained from the older crystallines, that they have been also much compressed, and have undergone, in consequence both of this and of their peculiar composition, some amount of mineral change. Of these ambiguities the most perplexing is the so-called Carboniferous gneiss of Guttannen,‡ a block of which is supposed to contain two stems of a plant, somewhat resembling a large calamite. The nature of this rock and of the apparent fossil is not to be settled in the off-hand way of which the pages of your PROCEEDINGS,§ afford an instance—especially when the *ex cathedra* judgment incorporates a mistaken identification of a common mineral.|| This remark, I may observe, is not the outcome of a passing glance, but of two prolonged examinations of the slab in the Museum at Berne, and two visits to Guttannen in order to study the rock in the field. I can readily understand that there is room for two opinions, but on the whole have come to the conclusion that the markings indicate plants and that the rock is not really a gneiss but only an "arkose." It presents us with this dilemma. If the so-called gneiss contain the remains of a plant, then it is no more a gneiss than the Torridon sandstone is a granite; and if the supposed

* A. Wills, *The Eagle's Nest*, ch. vii. A fine series was presented by that author to the Geological Museum at University College.

† Certainly this is not a member of the crystalline schist group. *Geol. Mag.*, 1896, p. 401.

‡ *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 390.

§ Vol. xiv, p. 43.

|| I have about twenty slices in my collection and hornblende is doubtfully present in one of them.

plant is only a pressure structure in a gneiss then no light is thrown on questions of metamorphism.

A rock called Verrucano, which is generally referred to the later part of the Carboniferous or to the Permian system, is often largely made up of fragments of the older crystallines, and presents the student with difficulties similar to those just mentioned. But here the puzzle, so far as I have seen, is of a simpler kind and can be solved by the expenditure of a little time and patience. The Rofna gneiss and the crushed gneissoid mass near Ilanz have been regarded by some geologists as the equivalent of the Verrucano, but I have failed to ascertain any scientific basis for this opinion.

With the Triassic Period a steady downward movement began to affect the whole Alpine region. This was more marked in the Eastern Alps, where eruptive action had been intense during the Permian Period and did not cease till after it had closed. In this region the crystalline floor, together with its burden of lavas and tuffs, sank slowly down, so that in Triassic times great masses of limestone and dolomite were deposited over a large area to the east of the Upper Innthal; the latter rocks sometimes attaining a thickness of more than 3,000 feet. I must excuse myself from entering into the difficult question of the origin of the dolomites of the South-eastern Tyrol, as it would occupy too much time, and it is not one to which I have devoted any very special attention.* Deposits of Triassic age are more local in the Central and Western Alps. In some districts they are wanting, evidently never having been deposited; in others, as in parts of the Pennine and Lepontine Alps, they are abnormal in character, being most commonly represented by a soft yellow tufaceous limestone, which frequently contains fragments of the older gneisses and schists. With this limestone, gypsum and dolomite are often associated. The deposit sometimes, as at the Pizzo Columbe, near the Lukmanier road, attains to a considerable thickness, but it often thins down to a few yards or even feet, and may exhibit great irregularity in a very limited area. In other districts, however, the Trias consists of ordinary limestone, etc., and is quite normal in character.

The Jurassic rocks overlap the Trias, have a wider extension, and are free from abnormalities. In the lower part they consist for the most part of dark argillaceous rocks (frequently cleaved), occasionally banded with hard brown sandstone, approaching quartzite. The former rocks, allowing for the cleavage, often remind us of some of the Liassic shales of England. They are commonly rather calcareous, and sometimes become true limestones. Belemnites, fragments of Pentacrinites, and other fossils are not infrequent, and these, as is well known, are sometimes curiously distorted by pressure. In the remaining part of the Jurassic

* See a very important paper by Dr. Maria Ogilvie in *Geol. Mag.*, 1894, pp. 1-49.

rocks limestones are rather abundant, sometimes forming thick masses. They weather to a pale fawn-tint, though when freshly broken they commonly appear rather dark in colour.

At this point we must pause in order to notice certain statements which have been made with much confidence, and appear to find favour with several leading geologists of Switzerland—namely, that in the Alps strata of Triassic and Jurassic age have undergone such metamorphoses that they may be properly classed with the crystalline schists. Of course, in a question such as this, everything depends on the sense in which words are employed. Probably almost all Jurassic or Palæozoic rocks in England, certainly all the limestones, have undergone some mineral change since the time when they were first deposited. Fragments of organisms have often lost their more minute structures, and have assumed that of mineral calcite. This obviously is incipient “marmorosis,” but we must be careful not to let the fine word act like a spell in paralysing our mental powers. Such an amount of “marmorosis” is exhibited by many an oolite of England, but this does not induce us to reckon Bath or Portland stone among the Metamorphic rocks. Similar changes are exhibited in Jurassic and Triassic rocks in the Alps, but that, for the same reason, has no real bearing on the present question. Still we must keep this distinction clearly in view, for I have more than once noticed that forgetfulness of it has produced very much, though quite unnecessary confusion. But to return to those cases to which the statements already mentioned more properly apply. I have personally investigated most of the instances by which they are supposed to be supported, with the following results.* In the first place a number of crystalline rocks—marbles, calc-mica-schists, etc., are set down as Trias, without any evidence at all in support of that reference beyond this, that they are distinctly more modern than some of the gneisses among which they occur, as if in folds or as pieces “wedged in” by thrust faults. But these so-called Triassic rocks correspond exactly with rocks which, in other places, can be proved to be much older than the Trias, while they are very different from those which can certainly be identified with Trias, and in no case graduate upward into strata containing Jurassic or indeed any other fossils. But this objection is asserted to be invalid on the ground that in certain parts of the Alps, Jurassic limestone can be proved to have been marmorized by pressure till it is indistinguishable from a schistose marble, while in others authigenous garnets and staurolites can be found lying side by side with Belemnites, Pentacrinites, and other Jurassic fossils. As regards the former of these statements, I have pointed out† that, in addition to other difficulties, the sections, confessedly perplexing, prove too much, for they show us

* See papers published in *Quart. Journ. Geol. Soc.* between 1890 and 1896.

† *Quart. Journ. Geol. Soc.*, vol. I (1894), p. 285 and vol. liii (1897), p. 16.

within a few feet of each other, two limestones, one of which is highly metamorphosed, the other practically unaltered. They also show us that the marble, whatever may have been the cause of its change from an ordinary limestone, has been greatly affected by pressure, which acted upon it *after it became marble*; that it is associated with other crystalline schists; and that its mode of occurrence in the field is suggestive of faulting. As regards the second statement I have demonstrated,* to the satisfaction, I believe, of all who have chosen to look at the evidence which I have laid before them, that it has no better support than a mistake in elementary mineralogy. Where fossils occur neither garnets nor staurolites are found in the rock (unless present as derivative fragments), but only certain ill-formed, very impure hydrous silicates, which have a slight superficial resemblance to rolled specimens of those minerals; but where authigenous garnets and staurolites do occur, the rock throughout is in a truly crystalline condition and not a trace of a fossil can be detected.

But it has been also asserted that some of these crystalline schists are proved to be Jurassic in age, because they form the inner part of a fold of which the outer is admitted to be Triassic. I have shown this interpretation to be untenable,† for if it were correct we should meet with great difficulties in accounting for the distribution and mode of occurrence of the beds in the supposed fold; we should have highly crystalline schists of Jurassic age overlying practically unaltered Triassic rocks, and we should find fragments of the former abundant in the latter! No doubt in one or two cases the collocation of the beds is rather remarkable if we adopt the hypothesis of thrust-faulting, but the difficulties raised by this are slight in comparison with those which are involved in the other.

In this connection it may be well to give a brief notice of a mass of rocks which occupies a large area in the more eastern part of Switzerland, especially in the district drained by the Hinter and Vorder Rhein. These are collectively called the *Bündner Schiefer* or *Schistes de Grisons*. Various statements have been made as to their age, and they have been supposed to be the happy hunting ground of the "progressive metamorphosist." Here, as a matter of fact, one name covers at least two very distinct groups of rock. The one, truly crystalline, consists of schistose marbles and mica-schists more or less calcareous, associated sometimes with quartz-schists and often with the green schists described above—in short the typical "upper schists," which here, as elsewhere in the Alps, may be often seen to overlie the gneisses and to underlie all recognisable Mesozoic or Palæozoic rocks. The other group is composed of grits and

* *Quart. Journ. Geol. Soc.*, vol. xlv (1890), p. 187; vol. l (1894), p. 297.

† *Ibid.*, vol. l (1894), p. 285 (with reference).

slates, which never pass beyond the stage of phyllites, and are not more metamorphosed than may be often observed in rocks on the same general line of strike in other parts of the Alps—that is to say, it is a group of Mesozoic rocks, affected to the usual extent by pressure. It is possible that in the district south of the Vorder Rheinthal, as is the case in the upper Rhonethal, a third group, somewhat intermediate in character, may locally occur, but on this point I will not venture to speak positively until I have had another opportunity of traversing a certain part of this district.

In regard to the later Secondary and the earlier Tertiary rocks of the Alps little need be said. Limestones and shales (or slates) are commoner than sandstones, while any coarse fragmental rock is rather rare and local. Here and there beds of very pure cream-coloured limestone occur, but there is nothing like the chalk of England. In these rocks fossils, as a rule, are not very common. True, I have never spent much time in hunting for them, but they do not catch the eye as one scrambles about, as they often do on the English hills. Under the microscope, however, fragments of organisms are frequently seen. Of course, in much-disturbed districts these are apt to be ill-preserved. But among the more coarsely clastic rocks one, which contains large fragments of mineral origin, demands a short notice, for it offers to us more than one difficult problem. In certain districts, in a deposit called the Flysch, which here is of Eocene age, conglomerates and even boulders occur, the volume of which sometimes amounts to several cubic yards. One of the most noted localities for these is the upper part of the Habkern-thal. The boulders lie in a more or less sandy mudstone, very rudely cleaved, in which also are “pockets,” or irregular streaky seams of coarse grit, containing often smaller fragments of granitic rock. Their mode of occurrence is peculiar; perhaps I may give the best notion of it by saying that they look as if, here and there, a barrow-load of gravelly stuff had been tipped over into the water in which the mud was being deposited. The granites of the boulders (five or six varieties have been observed) do not correspond with any now exposed in the Alps; one—a porphyritic rock, with some resemblance to that of Shap Fell—is very similar to a granite which occurs in the Schwarzwald. Similar deposits are found in the Flysch in other parts of the Alps, but I have myself examined only that in the neighbourhood of Sepey (Val des Ormonds). Here the boulders are abundant, though they do not run quite so large as in the Habkern-thal. Most of them, however, are a grey granite, which could be matched in the crystalline districts of the Alps. They usually occur in beds of more or less sub-angular breccia, which are regularly interstratified with grits and mudstones (slates), though now and then they may be found lying in the mudstone itself.

No thoroughly satisfactory explanation of the occurrence of these rocks has yet been given. That they have come from the ranges to the south seems almost impossible; that they have been derived from a vanished pre-Alpine range to the north seems hardly more probable. I think, however, that they have not travelled from a long distance, and it is possible that some rocky islands even then may have existed in the area now occupied by the Alps. The mode of transport is also a puzzle. Ice is the agent which naturally suggests itself. But this deposit occurs in the Eocene system, and that was a warm period; so that floating ice seems out of the question. And we cannot appeal to glaciers, for at that epoch the Alps were practically non-existent. I am unable to propose any satisfactory solution of the difficulty.

After the deposit of strata which are approximately contemporaneous with the Barton Beds of England, the development of the present Alpine chain began. The formation of the great parallel folds, the change over a large area from subsidence to upheaval, from deposition to denudation, produced, as was inevitable, a break in the succession of the sedimentary rocks, and greatly altered the circumstances under which the next group of beds was laid down. Some of them indicate the existence of shallow seas, but more often they were formed under fresh-water conditions, as deltas in lakes or even upon plains at the foot of mountains. These deposits occur only, so far as they can be identified, in the sub-Alpine region or on the outermost fringe of the chain, and they extend over what may be called by comparison the lowlands on both sides, but especially on the more northern one, of the Alps. On this account, seeing that this paper is already too long, I shall abstain from discussing them in detail, and merely state that the huge masses of conglomerate, which form the great foothills of the Oberland district, not to mention other parts of the Alps, were deposited by powerful rivers flowing in the same general directions and courses as those which still issue from the Alps.* To these conglomerates the name of *nagelfluh* has been given, and they have been separated, in accordance with the mineral nature of their pebbles, into the *nagelfluh polygenetique* and the *nagelfluh calcaire*; the distinction, I believe, being dependent solely on the character of the rocks in the basin which was being drained and denuded by each of the streams. It has been stated, indeed, that some of the pebbles represent rock which cannot now be found within these areas. So far as concerns the sedimentary rocks, I feel doubtful whether there is much ground for this assertion, especially when we remember that a very large quantity of

* One thing is noteworthy, that the difference in geological age between the newest of the beds uplifted in the Alpine masses and the oldest of those in the foothills is not great. Are we to suppose that Nature really did "hurry up" a little in making the Alps? But what will the severely orthodox Uniformitarians say?

the pebbles were supplied by strata which have now disappeared. As to the crystalline rocks which occur, though not very abundantly, in the *nagelfluh polygenetique*, it is true that certain of these, especially some reddish felstones and granites, cannot be identified, as we might expect they would be, within the area drained by the present rivers; but rocks not very dissimilar occur, and when we consider how much covered ground there is in every part of the Alps, we cannot be surprised at being unable to identify some of the comparatively rare constituents.* The suggestion that the watershed of the Alps then lay so far away to the south of its present position, that rocks could be transported from the lower ends of the great lakes, seems to me so improbable as not to require serious consideration.† In the *nagelfluh* and molasse of Switzerland (to speak of this only), many parts of the ranges which existed in Oligocene and Miocene times have found their graves.

Of the history of the Alps, after the second great upheaval of the chain, and of the work done during and since the Great Ice Age I must forbear to speak; for to enter upon that difficult but fascinating question would make the length of this paper comparable with that of an Alpine glacier at the period of maximum extension.‡ Permit me, however, in conclusion, to refer once more to the physical history of the Alpine chain. As it now exists it is the result, as I have just said, of two great sets of movements, which produced a group of parallel folds, curving round the area now drained by the Po and its tributaries; the one set dating from the end of the Eocene, the other of the Miocene. But the movement in at least the former case seems not to have been quite uniform or simultaneous over the whole area. The second certainly produced the most marked effects on the northern flank of the more central part of the Alps, while it did not greatly affect the eastern district.§ The first also commenced in the latter district at an earlier date than it did further west. But we must not forget the old saying, *Vixere fortes ante Agamemnona*. There were mountains here before the Alps. The Carboniferous breccias and conglomerates indicate the existence of powerful streams, or in other words, of a mountainous region in the immediate vicinity. The character and distribution of the Trias (not to mention anything of Permian age||) in the Central and Western Alps tells a

* The well-known porphyritic pitchstone on Goatfell (Arran) is a parallel case. Boulders also of the smaragdite-euphrodite of the Allalin Glacier are extremely abundant in the upper part of the Saasthal, yet comparatively little of that rock is now exposed.

† That the watershed of the Alps has advanced northward I have long maintained, but to grant on that account the possibility of the above change, would be, indeed, allowing an ell to be taken because an inch was given.

‡ The questions of the formation of cirques, valleys, and the erosive action of glaciers, especially in regard to the origin of the Alpine Lakes, were discussed in papers published in the *Quart. Journ. Geol. Soc.*, between 1871 and 1874, vol. xxvii, p. 312, vol. xxix, p. 382, vol. xxx, p. 479. See also *Geol. Mag.*, 1871, p. 535. The Physical Geography of the Alps also formed the subject of three lectures delivered at the Royal Institution and published in the *Alpine Journal*, vol. xiv, pp. 38, 105, 221.

§ See *Alpine Journal*, xiv, pp. 115-117.

|| The common absence of which is of course significant. For a fuller discussion of this subject see *Alpine Journal*, xiv, 45-47; see also *Id.*, 106, 107.

similar story. But there is another and not less strong proof that mountain masses existed where the present Alps stand, in and before these periods. Mountain ranges are the result of great folding movements of the earth's crust, and these movements are inscribed upon the rocks in the form of contortions, cleavage, and sheen-surfaces. But the fragments in the breccias, both of Triassic and of Carboniferous age, exhibit all these structures hardly less conspicuously than the crystalline masses themselves in the immediate neighbourhood.* No doubt the Tertiary earth movements were on a vast scale, for they have sufficed to produce a very marked cleavage, occasionally even some microfoliation, in the masses of Secondary rock, but the Archæan and probably the Palæozoic rocks were cleaved at a still earlier date. But the cleavages in all these rocks are often parallel, as if they were due to one and the same set of movements. Does this mean that the first effect of a long-continued and gradually increasing pressure, if it act in a new direction, is to obliterate the cleavage structure which has been produced by an earlier one, or, in other words, that a rock, once fissile, becomes coherent and finally splits in another direction? I think this may be not impossible, but will not venture to speak more strongly. Certainly a study of the microscopic structure of the older crystalline rocks in the Alps leads me to suspect that their history has often been a complex one; but for this reason I must not now attempt to discuss it, since, apart from the fact that your patience must be already exhausted, my investigations are not yet completed.

THE FORAMINIFERA OF THE THANET BEDS OF PEGWELL BAY.

WITH NOTES ON OTHER MICROSCOPIC ORGANISMS ; A DESCRIPTION OF THE SECTION AT PEGWELL BAY ; AND REMARKS ON THE CORRELATION OF THE THANET BEDS,

By HENRY W. BURROWS, A.R.I.B.A., AND RICHARD HOLLAND.

(Read December 4th, 1896.)

PLATES I, II, III, IV, V.

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I.—INTRODUCTION.

a. *Foraminifera previously recorded.*

THE Foraminifera hitherto recorded from the Thanet Beds of this country are but few in number. The following lists, so far as we are aware, include all the species that have been noted. Eliminating synonyms there are thus at present eleven known species, or varieties.

<i>Cristellaria calcar</i> , Linn., var. <i>platypleura</i> , Jones	} Mem. Geol. Surv., Vol. IV, 1872, p. 575.
<i>Nodosarina</i> (<i>Cristellaria</i>) <i>italica</i> , DeFr. (= <i>C. wetherelli</i> , Jones)	
* <i>Nodosarina</i> (<i>Nodosaria</i>) <i>raphanistrum</i> , Linn. (= <i>N. bacillum</i> , DeFr.)	
<i>Planorbulina</i> (<i>Truncatulina</i>) <i>lobatula</i> , W. and J. (= <i>Rosalina maria</i> , Jones)	
<i>Polymorphina lactea</i> , W. and J. (= <i>P. ampulla</i> , Jones, and <i>Globulina</i> of authors)	
<i>Rotalia beccarii</i> ? Linn (? = <i>Rosalina</i>)	

* In the Monograph Crag Foram., pt. iii, Pal. Soc., 1896, p. 218, the allocation of this species to the Thanet Sands is considered doubtful.

MARCH, 1897.]

<i>Polymorphina gibba</i> , d'Orb. (<i>ampulla</i> , Jones)	} <i>Cat. Foss.</i> <i>Foram.</i> <i>Brit. Mus.</i> , 1882, p. 19.
<i>Nodosaria acicula</i> , Lamk.	
<i>Cristellaria italica</i> , DeFr. (var. <i>wetherellii</i> , Jones)	
„ <i>cultrata</i> , (Montf.) (<i>platypleura</i> , Jones)	
<i>Truncatulina lobatula</i> , (W. and J.) (var. <i>mariae</i> , Jones)	} Parker Coll., <i>Brit. Mus.</i> <i>Nat. Hist.</i> (MS.)
<i>Cristellaria crepidula</i> , (F. and M.) var. <i>prima</i> , d'Orb.	
„ „ „ var. <i>varians</i> , Born.	
„ „ „ var. <i>simplex</i> , d'Orb.	
„ „ „ var. <i>protracta</i> , Born.	
<i>Nodosaria farcimen</i> (Soldani)	

These species are all from Pegwell Bay, and are not recorded from other localities, with the single exception that *Nodosaria raphanistrum* has also been met with at Goodnestone, east of Faversham, but the reference, as already mentioned, is doubtful.

The few species which have been recorded not having been assigned to their proper horizons in the Thanet series, it seemed to us desirable that a more careful examination should be made of the several beds of, at least, some one typical section, in order that the known species should, if possible, be properly located, and others added.

b. Section at Pegwell Bay.

Pegwell Bay affords by far the best exposure of the Thanet Beds. It is quite clear in its section, and not liable to serious misinterpretation; and it does not include the risk of containing an admixture of recent species, washed in from the sea, as is in part possible with the lower beds at Herne Bay and Reculvers. We were also induced to select this section as Mr. Percy Emary had kindly supplied us with a sample of one of the lower beds (F) which proved to be rich in Foraminifera.

To avoid, as far as possible, all chance of error, we did not trust to old material already in our possession from Pegwell Bay, but visited the section, and selected specimens from each of the beds. The result of the detailed examination of these specimens will be dealt with in due course, but before discussing them we will briefly describe the section at Pegwell.

The beds form low cliffs (Fig. 1) and stretch, broadly speaking, from north-east to south-west, dipping very slightly to the south-west. They rest upon the Upper Chalk (zone of *Micraster cor-anguinum*) at the Broadstairs, or north-east, arm of the Bay, and show the vertical section given on p. 22.

Some discussion has been waged over this section, both with regard to its actual thickness and as to the interpretation to be placed upon the age of some of the beds.

The bed A has particularly been the subject of inquiry with regard to its geological position. Mr. J. Starkie Gardner, in his

THANET BEDS. {
 A. Drift Loam.
 B. Yellow and buff sands.
 C. Greenish-grey and buff sands.
 D. Dark greenish-grey sandy marl.
 E. Dark grey shaly marl, with iron stains.

THANET BEDS. {
 F. Dark grey, green and buff to orange sandy marl, in bands.
 G. Red of green-coated flints.
 H. (Type chalk of Boxclairs (zone of *Murister cor- anguinum*))

FIG. 1.—SKETCH SECTION OF THE CLIFFS AT PEGWELL BAY.



paper on the Lower London Tertiaries,* gives a section differing somewhat from that shown in the *Survey Memoirs*. In the Survey section this bed is described† as "Light-brown loam, often with flints and bits of chalk at the bottom, sometimes a few black flint-pebbles and shells washed out of the Thanet Sand below."

Mr. Gardner in the paper alluded to, on the other hand, divides this bed into two portions, an upper of Drift Loam and a lower of Buff Clayey Sand with black pebbles at the base, and he states on the plate that the last-named bed is not noticed by either Prestwich ‡ or the Survey. In the latest edition of the *Survey Memoirs*§ Mr. Whittaker devotes some attention to this question, and says: "One of the reasons given [by Mr. J. S. Gardner] for including the Sand that has been mapped as belonging to the Woolwich Series in East Kent with the Thanet Beds is based on a mistake. The author says that 'at Pegwell a layer of black flint pebbles occurs in what is acknowledged to be Thanet Sands.' The layer in question is really at the base of the Drift Brickearth, and has not been acknowledged to belong to anything else; Mr. Gardner indeed himself infers this in his plate, though only saying 'apparently classed as Drift.' The statement (on the plate) that it is 'not mentioned by Prestwich or

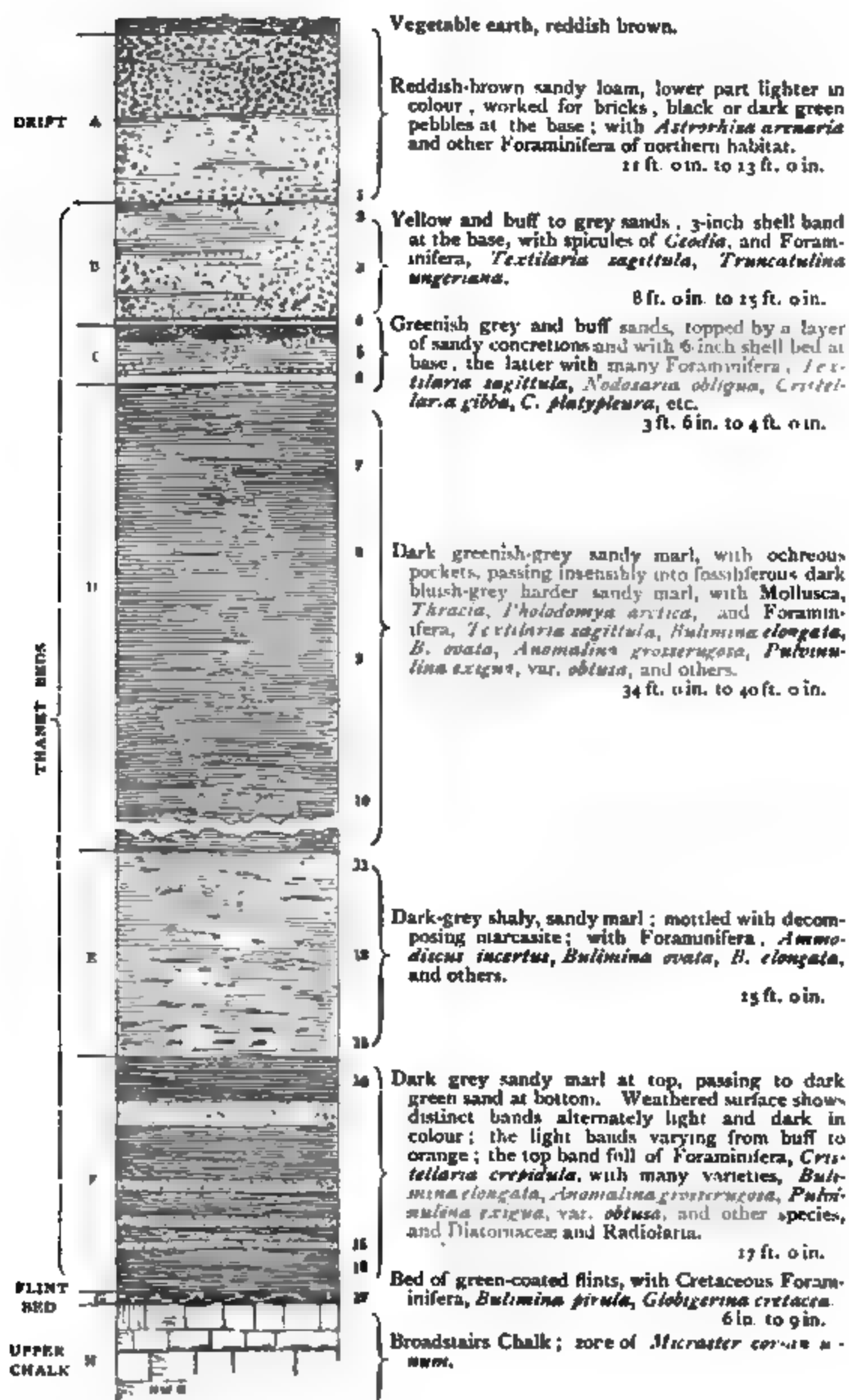
* *Quart. Journ. Geol. Soc.*, vol. xxxix, 1883, p. 204.

† *Mem. Geol. Surv.*, vol. iv, 1879, p. 96.

‡ *Quart. Journ. Geol. Soc.*, vol. viii, 1852, pp. 275 et seqq.

§ *Mem. Geol. Surv.* (Geology of London), vol. i, 1889, p. 97.

FIG. 2.—VERTICAL SECTION OF THE CLIFF AT PEGWELL BAY.



the Survey' is incorrect, for it has been mentioned by both as Drift."

From the Drift bed A to the base of the Thanet Series at Pegwell Bay the section is quite clear; but the green-coated flint-bed G has been the subject of considerable controversy, both as to its origin and as to whether it should be classed with the Thanet Beds or with the underlying chalk.

Mr. Dowker* suggested that the green-coated flint-bed was due to sub-aërial denudation of the chalk before the deposition of the Thanet Beds.

Mr. J. S. Gardner† contends that as the Thanet fauna was deposited within the Laminarian Zone [low water to 15 fathoms] the peculiar green tint was probably caused by the sea-weed in which the flints were imbedded.

Mr. Whitaker‡ summarises the various views which have been expressed by the authors already mentioned, by Prof. Morris, Prof. T. McKenny Hughes, and others, and comes to the general conclusion that the green-coated bed is due to the removal of chalk by chemical action, either before, but more probably subsequent to, the deposition of the Thanet Sand; and that during that time the flints also received their coating of silicate of iron.

As with the age of the beds, so with their relative thickness close agreement is not to be found.

The bed A is stated by Mr. Gardner to be 12 feet thick. We notice that it is somewhat variable in its dimensions, the upper division varying from 5 to 6 feet, and the lower from 6 to 7 feet, so that in places it measures at least 13 feet.

The beds B and C taken together, when measured by the Survey, showed 12 to 15 feet thick; Mr. Gardner computes them at 10 feet, and we consider they vary from 12 to 19 feet. This apparent discrepancy can be readily explained. The beds, no doubt, are variable in themselves, and it depends to some extent upon the position in which they are measured, and upon the different conditions pertaining at different periods, consequent upon the cutting back of the cliffs. Bed B is certainly variable, in our view ranging from 8 to 15 feet, while C is more constant and averages 3 feet 6 inches to 4 feet.

With the beds D and E there is a similar divergence in the measurements. By the Survey they are stated together to be 40 feet thick, Mr. Gardner assigns 49 feet as the thickness, and we are inclined to consider that bed D alone is 40 feet thick, making a total for beds D and E of, say 55 feet.

Bed F when measured by the Survey showed 9 feet, and

* *Geol. Mag.*, vol. iii, 1866, pp. 210, 239.

† *Quart. Journ. Geol. Soc.*, vol. xxxix, 1883, p. 202.

‡ *Mem. Geol. Surv.* (Geology of London), vol. i, 1889, pp. 104-106, and *Mem. Geol. Surv.* vol. iv, 1872, p. 58.

when seen by Mr. Gardner 17 feet thick ; which thickness it still retains.

The base bed of dark clayey greensand (part of our bed F), recorded as $1\frac{1}{2}$ feet by the Survey, is included in the above-mentioned 17 feet.

The following shows the differences of measurements at various times :

		Survey (1872).	J. S. Gardner (1883).	H. W. B. & R. H. (1896).
Drift.	A.	?	12 ft.	11 ft. to 12 ft.
	B.	12 ft. to 15 ft.	{ 7 ft.	8 ft. to 15 ft.
	C.		{ 3 ft.	3 ft. 6 in. to 4 ft.
THANET SERIES.	D.	40 ft.	{ 34 ft.	40 ft.
	E.		{ 15 ft.	15 ft.
	F.	9 ft. 1 ft. 6 in.	17 ft.	17 ft.
	G.		?	6 in. to 9 in.
Flint bed.	G.	?	?	6 in. to 9 in.

In selecting our specimens we were careful to take them, as will be seen by reference to Fig. 2, so that their exact position might be known. We measured up or down from well defined bands.

c. *Correlation of Thanet Beds with those of Belgium and France.*

A few words may be said upon the correlation of the English Thanet Beds with those of similar age upon the continent.

The late Sir J. Prestwich, in his paper on the "Correlation of the Eocene Strata in England, Belgium, and France,"* in comparing the Thanet Sands with the Lower Landenian says: "There can be no doubt of the synchronism of these English and Belgian deposits," and in the classification he then proposed,† the Thanet Sands of England were correlated with the Lower Landenian and Heersian in Belgium and with the sands of St. Omer, Douai, and the lower sands of La Fère in France.

Mr. G. F. Harris dissents somewhat from this view of the correlation. He had previously pointed out‡ that the Landenian Beds overlie the Heersian, and that the Lower Landenian has a fauna quite unlike that of the Thanet Beds; so that while admitting the Lower Landenian to be in part equivalent to the Thanet Beds, he is inclined to think they also represent newer beds. He regards the Heersian Beds as the true equivalents of the Thanet Beds and the "beds which entomb the Gelinden flora, homotaxial with the lower part of our Thanet Beds."

d. *Foraminifera of Foreign Beds of Thanet Age.*

The Foraminifera of beds of this period appear to have received but scanty attention upon the continent. In a letter to

* *Quart. Journ. Geol. Soc.*, vol. xlv, 1888, p. 91.

† *Op. cit.*, p. 108.

‡ *Geol. Mag.*, Decade iii, vol iv, 1887, pp. 110, 111.

us on the subject in answer to our inquiries, M. Gustave Dollfus says that no author has yet to his knowledge noted any Foraminifera in the Thanet Sands of the Paris Basin. He doubts if they have hitherto been properly sought for, but in any event he believes them to be very rare.

M. Dollfus has himself carefully studied the fauna of the *Sables glauconieux inférieur*, and has only found a single species of Foraminifera, which he refers to *Rosalina mariae*, Jones.

At Châlons-sur-Vesle there are, if his memory serves him rightly, some *Polymorphinæ*, but the subject generally has been neglected in France.

M. Dollfus also informs us that some Radiolaria have been recorded from the *Tufeau de la Fère* (zone of *Arctica morrisii*) but no Foraminifera were apparently met with.

With regard to Belgium, M. E. Van den Broeck is good enough to inform us that no lists of Foraminifera have yet been published of either the Heersian or of the Landenian Beds. The Rhizopodal fauna is, however, rich in individuals, if not in species, particularly of the genera *Dentalina*, *Fronicularia*, and *Marginulina* among others. It would be interesting to compare the fauna of the Belgian deposits with that of our own beds, and M. Van den Broeck has kindly promised to forward us some material which will, we trust, enable us to institute a comparison at a later date.

II.—LITHOLOGICAL AND PALÆONTOLOGICAL CHARACTERISTICS OF THE SEVERAL BEDS AT PEGWELL BAY.*

Bed A. Drift. Specimen 1.—A pale-brown, fine grained sandy loam, with a scattered band of greenish-black flint pebbles at the base. The larger grains are principally fragments of mollusca, and sub-angular and well-rounded grains of quartzose sand, cemented in part into small concretionary masses by an oxide of iron. A very large proportion (84 per cent.) of the bed is composed of very small angular and sub-angular quartzose sand, with some flakes of mica and a few grains of glauconite. Organic remains are generally scarce. Our washings yielded: a small *otolith*, numerous fragments of mollusca, one Ostracod valve, which Professor T. Rupert Jones, who kindly helped us with the Ostracoda throughout, considers to be near to *Cythereis bowerbankiana*, a few spines of Echinoidea, and still fewer spicules of Tetractinellid sponges.

The Foraminifera are not well represented in this bed, with the

* *Note.*—The specimens 1 to 17 inclusive were taken from each bed at various levels, as indicated by the small numerals on the section, Fig. 2. A table showing the size of component particles and amount of insoluble residue is appended, p. 30.

exception of two species, which are rather common. These are the arenaceous form, *Astrorhiza arenaria*, and the hyaline *Truncatulina akneriana*. The other species of Foraminifera are rare, but it should be noted that the forms met with are such as are now abundant in high latitudes, though they are not confined to northern waters.

Bed B. Specimen 2.—Colour a pale fawn. This bed is principally formed of rather angular and splintery grains of quartzose sand of very small size, cemented in part into concretionary masses with carbonate of lime. The minute granules of sand are in many cases cemented to the entombed organisms, which are not so rare as they appear to be at first sight; but it is difficult to extract recognisable species. Mollusca, represented in our gatherings by fragments only, are not rare. The Ostracoda are represented by two species, probably referable to *Cythereis bowerbankiana* ? and *Cytheridea papillosa*. Spines of Echinoidea are rather common, and spicules of Tetractinellid sponges and of Alcyonarian corals not rare. Some minute ovoid bodies in this specimen particularly attracted our attention, and we submitted them to Dr. G. J. Hinde. As these organisms are abundantly distributed throughout the material we have collected at Pegwell Bay we venture to quote the remarks upon them which Dr. Hinde was good enough to favour us with. He says: "The small ovoid bodies from the Thanet Sands of Pegwell Bay are detached dermal spicules of siliceous Tetractinellid sponges belonging to the genus *Geodia* probably. These sponges have a thick outer crust composed of the same kind of microscopic bodies as in your slide. The spicules are made up of numerous diverging fibres starting from a centre, and their heads project slightly beyond the general surface of the spicules like the heads of so many pins on the outside of a pincushion. There is a small round smooth spot in each where the animal filament was attached which held them in position when the sponge was alive. They vary in size and form in different species of the genus and even in the same specimen. Some are round, nearly, others ovoid or reniform. They occur detached in most deposits where siliceous sponges are present. . . . In some of the fossil forms the central portions are dissolved or removed, and give rise to the apparent air-bubble which you refer to in your specimens. No alteration in other respects have gone on in yours; they still remain in their opalized condition, giving no colours in polarized light between crossed nicols; those in the chalk are now usually chalcedonic or wholly crystalline. The body spicules of these *Geodia* sponges consist of needle, fusiform spicules, and trifid spicules." Dr. Hinde also favoured us with drawings of similar spicules of *Geodia* from the upper chalk of Norwich and of Westphalia, and of *Geodia japonica*, recent from Japan, by which it would seem that the spicules from Pegwell Bay are rather

larger than the recent species, and somewhat smaller than those from the cretaceous beds referred to.

In the finest washings from this Bed we notice a few Radiolaria, more or less fragmentary, but probably belonging to the genus *Cænosphæra*.

The Foraminifera are of few species, and very rare, with the exception of *Textilaria sagittula* and *Nodosaria obliqua*, which are rather common.

Bed B. Specimen 3. This specimen is very similar to the last described, but the sand-grains are more compacted into concretions. Glauconite is not rare. Organic remains are very similar to those in specimen 2, except that we have not detected any Ostracoda or Radiolaria. The common Foraminifera are the same as in specimen 2.

Bed B. Specimen 4 (3-inch shell-band). A very similar specimen to No. 2, so far as the matrix is concerned; but, being a shell-band, fragments of mollusca are much more abundant. Other organic remains are scarce; one valve of an Ostracod, *Cytheropteron* sp., was found; spicules of *Pachastrella* and *Geodia* occur sparingly, and in the finest sediment after washing a few Radiolaria, probably *Cænosphæra*. The common Foraminifera are as in the other specimens from bed B; *Truncatulina ungeriana* is, however, rather more plentiful than in the other gatherings from this bed.

Bed C. Specimen 5. In colour a dull earthy fawn or buff, composed of fine angular grains of quartzose sand, in part cemented with carbonate of lime. A large proportion of the grains quite clear, mixed with others stained with limonite or other oxide of iron. Bright green grains of glauconite not rare. Organic remains are very scarce, principally fragments of mollusca. One valve of an Ostracod, *Cytheridea papillosa*, was detected, with a few spines of Echinoidea and spicules of *Geodia*. The Foraminifera are few in number. Poor and stunted specimens of the following species, among others, were met with: *Textilaria sagittula*, *Bulimina ovata*, *B. elongata*, *Cristellaria platypleura*, *Truncatulina ungeriana*, and *Anomalina grosserugosa*.

Bed C. Specimen 6 (6-inch shell-band). In colour and composition very like the last-described specimen, the large particles being almost wholly fragments of mollusca. Some of the glauconite grains simulate casts of Foraminifera, showing a lobulated outline. In addition to the mollusca other organic remains occur. We notice spines of Echinoidea, and several specimens of Ostracoda, allied to, if not identical with, *Cythereis quadrilatera*. The Foraminifera are fairly abundant; indeed this is one of the richest beds in the Pegwell Bay section for representatives of the Class. *Cristellaria gibba*, *C. platypleura*, and intermediate varieties approaching *C. cultrata* are very

abundant, together with *Textilaria sagittula* and *Nodosaria obliqua*, while *Truncatulina ungeriana* and *Anomalina grosserugosa* are rather common. A fair number of other species occur, but individually they are more rare.

Bed D. Specimens 7, 8, 9, and 10. Each of these specimens is similar in colour and composition, being a dark grey, hard, sandy marl, breaking for the most part with a tendency to "conchoidal" fracture. When the carbonate of lime is removed the matrix is seen to consist of very minute grains of quartzose sand, with a few grains of glauconite and flakes of mica. For the most part these specimens are exceedingly poor in organic remains. Ostracoda are represented in specimen 9 by one valve allied to *Bythocypris silicula*; Echinoidea in each specimen by a few spines; Bryozoa in specimen 7 by one example, which Dr. J. W. Gregory, who was good enough to examine it, refers to the genus *Filisparsa*; Radiolaria by *Cænosphæra*, in specimens 7 and 8; Sponges by spicules of *Geodia*, sparingly in each specimen; Diatoms by very small forms of *Coscinodiscus* in the finest washings from each specimen.

The Foraminifera are not well represented in any of the specimens. The most common are *Bulimina ovata* and *B. elongata*, *Textilaria sagittula*, *Truncatulina ungeriana*, *Anomalina grosserugosa*, and a variety of *Pulvinulina exigua* (var. *obtusa*, nov.)

Bed E. Specimens 11, 12, and 13. It is only in the mass that this bed differs from Bed D, as it is more shaly and mottled with iron and decomposing pyrites or marcasite. Each of the samples examined presents much the same microscopic characters as those of Bed D, except that there are many particles of ferruginous material and more abundant glauconite, especially in No. 13. Organic remains are again very scarce, Echinoidea, Radiolaria, Spongida, and Diatomaceæ being represented as in Bed D, and very sparingly. The Foraminifera are rare, with the exception of *Bulimina ovata* and *B. elongata*. Among the rarer forms may be noted *Anmodiscus incertus*, *Chilostomella ovoidea*, *Cristellaria arcuata*, *Cristellaria platypleura*, *Pullenia sphæroides*, *P. quinqueloba*, and others as tabulated.

Bed F. Specimen 14. This sample is a dark grey, hard, sandy marl, breaking with a "conchoidal" fracture. The colour is rather darker than in Bed E, and it has in consequence been called "the black band," by Dr. A. Rowe. In composition it is very similar to the gatherings from Bed E, very fine-grained quartzose-sand, cemented by carbonate of lime. The fauna of this bed is, in many respects, the richest we have met with in the Thanet Beds of Pegwell Bay.

Sponges are represented, as in other gatherings, by ovoid spicules of *Geodia*; Radiolaria, though the specimens are small

and rare, by *Cænosphæra*, *Stylosphæra* and *Ceratospyris*; and Diatomaceæ by the genera *Triceratium*, *Coscinodiscus*, and *Omphalopelta*. Some of the specimens of the two last-named genera are large and well developed examples, and it is interesting to note that they are comparable with some Diatoms recorded from the London Clay by W. H. Shrubsole and F. Kitton* ; and, like the species recorded by those authors, occur, not in the siliceous condition, but as pseudomorphs in dark brown glistening iron-pyrites. The Foraminifera are abundant, and the bed is particularly rich in the large ensiform varieties of *Cristellaria crepidula*, figured on Plate I. More common, but not so conspicuous by reason of their small size, are *Bulimina elongata*, and the new variety of *Pulvinulina exigua*. Among the rarer species may be noted *Ammodiscus incertus*, *Dentalina communis*, *Nodosaria farcimen*, and *Pullenia quinqueloba*.

Bed F. Specimen 15, from near the base of the Thanet Series, is composed of a pale fawn-coloured sand, of exceedingly fine grain, sharp and angular, stained with limonite or other iron salt. We have failed to detect a trace of any organic remains.

Bed F. Specimen 16. This is often referred to as the "greensand-bed," and its lithological characters have been discussed at length by Miss M. J. Gardiner,† who shows that the principal component minerals are quartz, about 45 per cent., flint in angular chips, 20 per cent., with a fair proportion of glauconite ; which is, however, less well-developed than in most greensands.

In addition to the minerals already referred to, Felspar, Zircon, Rutile, Tourmaline, and other rarer minerals are also found in this bed. Miss Gardiner obtained casts of Foraminifera, "probably of the genera *Planorbulina* and *Textilaria*." We have not been so fortunate as to detect any with certainty, but the lobulated character of many of the glauconite grains suggests a Foraminiferal origin.

The siliceous spherical (or ovoid) spicules of *Geodia* are alluded to in Miss Gardiner's paper, but they are erroneously, though with doubt, referred to the Radiolaria or Diatomaceæ.

Bed G. Specimen 17. (Bed of green-coated flints.) This bed calls for but little remark ; it is chiefly composed of broken, angular, and splintery fragments of flint, green-coated in part, with many grains of glauconite and other minerals, more or less cemented by ferruginous material.

We have only detected a few specimens of Foraminifera after a long search, and they are referable to cretaceous species ; particularly *Textilaria globulosa*, *Bulimina pirula*, *Globigerina cretacea*, and some poor *Truncatulina*.

* *Journ. Roy. Micro Soc.*, 1881, p. 381, pl. v.

† *Quart. Journ. Geol. Soc.*, 1888, vol. xlv, pp. 755-760.

Table showing amount of insoluble residue and size of component particles of specimens of the Various Beds at Pegwell Bay.

Bed.	No. of Specimen.	Percentage of Insoluble Residue.	Percentage amount of Residue on Meshes.			
			$\frac{1}{30}$ inch.	$\frac{1}{80}$ inch.	Less than $\frac{1}{80}$ inch.	
A.	1	80.00	2.0	14.0	84.0	Drift.
B.	2	—	0.5	5.0	94.5	
"	3	80.00	9.0	48.5	42.5	
"	4	—	19.0	60.0	21.0	Thanet Series.
C.	5	—	7.0	24.0	69.0	
"	6	84.00	0.0	5.0	95.0	
D.	7	—	24.0	47.0	29.0	
"	8	—	19.0	59.0	22.0	
"	9	82.00	25.7	52.9	21.4	
"	10	—	30.0	55.0	15.0	
E.	11	—	15.0	62.0	23.0	
"	12	88.00	19.0	56.0	25.0	
"	13	—	7.0	52.0	41.0	
F.	14	64.00	8.0	45.0	47.0	Bed of green-coated flints.
"	15	—	13.0	19.0	68.0	
"	16	—	8.0	42.0	50.0	
G.	17	90.00	20.0	48.0	32.0	

NOTE.—All molluscan fragments above $\frac{1}{30}$ inch sifted off.

III.—THE FORAMINIFERA.

In a review of the Foraminifera from the Pegwell Bay Section, one of the most striking features is the entire absence of the porcellaneous type. We have not been able to find a single specimen nor even a cast in glauconite. It is noteworthy that the whole Cretaceous system which precedes the Thanet series in time shows, so far as it has been at present worked out, great poverty in forms of this type. M. Berthelin* reports the entire absence of porcellaneous Foraminifera from the beds of L'Etage Albien de Montcley. Mr. Chapman records† a very limited and sparsely-represented number of species from the Gault of Folkestone. The same author found the *Porcellanea* exceedingly rare in the (Neocomian) Bargate Beds of Surrey, and equally so in the Phosphatic Chalk of Taplow.‡ Messrs. Burrows, Sherborn, and Bailey met with very few specimens in the Red Chalk of Speeton.§ Not one specimen is recorded in d'Orbigny's paper on the Craie Blanche;|| and the family is altogether absent from Mr. Joseph

* *Mem. Soc. Geol. France*, 1880, Ser. 3, Tom. 1, p. 17.
† *Journ. Roy. Mic. Soc.*, 1891, pp. 572-575.
‡ *Quart. Journ. Geol. Soc.* 1892, vol. xlviii, p. 516.
§ *Journ. Roy. Mic. Soc.*, 1890, pp. 551-552.
|| *Mem. Soc. Geol. France*, 1840, Tom. 1, Part 1.

Wright's list* of the Foraminifera from the Chalk of the North of Ireland ; and also (save for one undetermined specimen) from the collection of Cretaceous Foraminifera in the British Museum.† Other workers on Cretaceous Foraminifera—Reuss, for example—have noted a similar absence of the *Porcellanea*.

On the other hand, the *Spiroloculina* in particular have been found abundantly by MM. Terquem and Berthelin in the beds of the Middle Lias at d'Essey-les-Nancy (*Mem. Soc. Geol. France*, 1875, Sér. 2, Tom. x), and there are records by other authors of the occurrence of *Spiroloculina* and other genera of the Porcellanous type in beds of pre-cretacean age.

FAMILY LITUOLIDÆ.

SUB-FAMILY Trochammininæ.

AMMODISCUS, Reuss.

1. *Ammodiscus incertus* (d'Orb.).

Operculina incerta, d'Orb, *Foram. Cuba*, 1839, p. 71, Pl. vi, Figs. 16, 17 ; *Trochammina incerta*, Haeusler, 1882, *Ann. Mag. Nat. Hist.*, Ser. 5, vol. x, p. 54, Pl. iii, Fig. 6 ; *Ammodiscus incertus*, Brady, *Report Chall.*, vol. ix, 1884, p. 330, Pl. xxxviii, Figs. 1-3.

The specimens of *A. incertus* from Pegwell Bay are of the elliptical variety, and not unlike Fig. 6 of Pl. III in Haeusler's paper above referred to. They are small, very fine in texture, pure white, generally smooth, and, under a low power, have a strong resemblance to *Cornuspira*. Specimens were found only in Beds D, E, and F, and always rarely. The largest specimen was from Bed D, but it was somewhat abnormal in growth—being more than usually compressed, and having a somewhat angular periphery.

FAMILY TEXTILARIDÆ.

SUB-FAMILY Textilarinæ.

TEXTILARIA, Defrance.

2. *Textilaria sagittula*, Defrance.

Pl. II, Fig. 10.

T. sagittula, Def., 1824, *Dict. Sci. Nat.*, vol. xxxii, p. 177 ; vol. liii, p. 344 ; *Atlas Conch.*, Pl. xiii, Fig. 5 ; Brady, *Report Chall.*, 1884, vol. ix, p. 361, Pl. xlii, Figs. 17, 18.

This form calls for little remark save as to its range. In the

* *Cat. Foss. Foram. Brit. Mus.*, p. 89.

† *Op. cit.*, p. 86.

Pegwell Beds it seems to make its appearance first in the upper part of Bed E, where we found it rarely. In Bed D it is less rare; in Bed C common; and very common in Bed B. All the specimens are of about the average size, and of the usual texture; but the final chambers are rather more largely grown than in typical specimens.

SUB-FAMILY *Bulimininae*.

BULIMINA, d'Orb.

3. *Bulimina ovata*, d'Orb.

Pl. II, Fig. 11.

B. ovata, d'Orb., *For. Foss. Vienne*, 1846, p. 185, Pl. xi, Figs. 13, 14; Brady, *Report Chall.*, 1884, p. 400, Pl. I, Fig. 13.

4. *Bulimina elongata*, d'Orb.

Pl. II, Fig. 12.

B. elongata, d'Orb., *For. Foss. Vienne*, 1846, p. 187, Pl. xi, Figs. 19, 20; Brady, *Report Chall.*, 1884, p. 401, Pl. li., Fig. 1.

These *Buliminae* are among the most noticeable forms in our gatherings from Pegwell Bay. The range of the two species extends throughout the series of beds, but *B. elongata* occurs plentifully in Bed F, where we did not find its fellow, and *B. ovata* is met with rarely in Bed B, while our specimens of *B. elongata* were not obtained higher than Bed C. Both species are common in Bed E. In Bed D, *B. ovata* is rather common, and *B. elongata* rare; and in Bed C both species are rare.

BOLIVINA, d'Orb.

5. *Bolivina ænariensis* (Costa).

Brizalina ænariensis Costa, 1856, *Atti dell' Accad. Pont.*, vol. vii, p. 297, pl. xv, fig. 1; *Bolivina ænariensis*, Brady, *Report Chall.*, 1884, vol. ix, p. 423, pl. liii, figs. 10 and 11.

One very small example was found in the 6-inch shell-band of Bed C. So far as is known, the "species" in recent seas is confined to comparatively shallow waters. As a fossil we believe it has not previously been recorded from deposits older than the Miocene.

FAMILY *CHILOSTOMELLIDÆ*.

CHILOSTOMELLA, Reuss.

6. *Chilostomella ovoidea*, Reuss.

C. ovoidea, Reuss, 1849, *Denkschr. d. k. Akad. Wiss. Wien*, vol. i, p. 380, pl. xlviii, fig. 12; Brady, *Rep. Chall.*, 1884, vol. ix, p. 436, pl. lv, figs. 12-23.

One specimen of this not uncommon Tertiary fossil occurs in our gatherings from the upper part of Bed E.

FAMILY LAGENIDÆ.

SUB-FAMILY Lageninæ.

LAGENA, Walker and Jacob.

7. *Lagena apiculata* (Reuss).

Oolina apiculata, Reuss, 1850, Haidinger's *Naturw. Abhandl.*, vol. iv, p. 22, pl. i, fig. 1; *L. apiculata*, Brady, *Rep. Chall.*, 1884, p. 453, pl. lvi, figs. 4, 15-18.

8. *Lagena lævis* (Montagu).

Vermiculum læve, Montagu, 1803, *Test. Brit.*, p. 524; *L. lævis*, Brady, *Rep. Chall.*, 1884, p. 455, pl. lvi, figs. 7-14, 30.

9. *L. lævigata* (Reuss).

Fissurina lævigata, Reuss, 1849, *Denkschr. d. k. Akad. Wiss. Wien*, vol. i, p. 366, pl. xlvi, fig. 1; *L. lævigata*, Brady, *Rep. Chall.*, 1884, p. 473, pl. cxiv, fig. 8.

10. *L. reticulata* (Macgillivray).

Lagenula reticulata, Macgillivray, 1843, *Moll. Anim. Aberdeen*, etc., p. 38.

11. *L. marginata* (Walker and Jacob).

Serpula (*Lagena*) *marginata*, Walker and Jacob, 1784, *Test. Min.*, p. 2, pl. i, fig. 7; *L. marginata*, Brady, *Rep. Chall.*, 1884, vol. ix, p. 476, pl. lix, figs. 21-23.

The *Lagenæ* are very rare indeed in the Pegwell Bay beds, and the specimens found are small. *L. apiculata* (one specimen) was found in Bed E, *L. lævis* (one specimen) in Bed F, *L. lævigata* (one specimen) also in Bed F, *L. reticulata* (two specimens) in Bed B, *L. marginata* (one specimen) in Bed C.

The enumeration of these very rare and, so to speak, accidental occurrences of *Lagenæ* leads us to call attention to the uselessness for all practical purposes beyond a mere record of range of many of the published lists of Foraminifera occurring in different formations and horizons. Too often such lists record the *occurrence* of the species only, without the slightest clue as to the frequency with which they occur, or the condition in which

they are found—whether well grown or starved, for example. Where a series of forms occurs in such profusion, and in such vigour of growth, as the ensiform *Cristellaria* assume in Bed F of the Pegwell Bay Section, there can be little doubt that the conditions under which that particular horizon was laid down must have been peculiarly favourable to the particular form of Foraminifera, and the record becomes valuable for comparison with other records of occurrences of the same type in recent or geologic times. Far otherwise is the case with records of the occurrence of single or very few specimens of a particular form. It is by no means certain that such forms ever lived within many miles of the spot in which the dead shells are found; and this is especially the case with the smaller varieties of Foraminifera.

With a view to obtaining some insight into this part of the question of the distribution of Foraminifera, we made an experiment in September, 1895, which it may, perhaps, be useful to record here. Towards the end of the month mentioned, on a fine day, and after a prolonged period of fine weather, a tow-net was taken out into the English Channel to a point about three miles due south of the mouth of the River Arun, and towed for about a mile in a direction still due south, and at the surface of the water. The depth of water was nine fathoms at the starting point, and doubtless gradually increased, though not rapidly. There was just enough wind to sail by, and the water was almost absolutely free from floating weed. The solid contents of the tow-net, when taken in, were very meagre in quantity, doubtless owing in no small degree to the fact that the net, or bag, being made of calico in order to stop the smallest organisms, did not admit of much draught of water through its substance. The bulk of the solid matter proved to be minute crustacea, with which we were not concerned. There was also a considerable percentage of very fine sand and a very considerable number of perfect Foraminifera. The Foraminifera comprised some thirty "species," including several *Lagenæ* and one species of *Haplophragmium*. There were several specimens of some of these forms. The *Haplophragmium*, for instance, was rather common, and *Lagena lævis* and *L. clavata* were distinctly so.

Whether these forms were living at the surface, or whence they were derived, does not affect the question under consideration, namely, the distribution of fossil Foraminifera; but it is obvious that the shells thus taken from the English Channel might have floated away to very great distances before they finally found a resting place on the sea-floor or on the beach; and there can be no doubt that many of the *smaller* forms, at any rate, found in fossil deposits, whether belonging to species pelagic in their habit or not, have undergone transportation of this nature.

SUB-FAMILY *Nodosarinæ*.*NODOSARIA*, Lamarck.12. *Nodosaria farcimen* (Soldani).

(Pl. II, Fig. 4.)

Orthoceras farcimen, Soldani, 1791. *Testaceographia*, vol. i, pt. 2, p. 98, pl. cv, fig. O; *Nodosaria* (*Dentalina*) *farcimen*, Brady, 1884, *Rep. Chall.*, vol. ix, p. 498.

We found no complete specimen of this form in our material, but fragments sufficiently large for identification were met with very rarely in Beds D and E. Through the kindness of Dr. Henry Woodward we are able to figure a fine and almost perfect specimen, which is preserved in the Parker Collection of Fossil Foraminifera in the British Museum (Natural History), and which was obtained by Dr. A. Rowe from Bed F.

13. *Nodosaria raphanus* (Linné).

(Pl. II, Fig. 8.)

Nautilus raphanus, Linné, 1767, *Syst. Nat.*, 12th ed., p. 1164, 283; *Nodosaria raphanus*, Brady, 1884, *Rep. Chall.*, vol. ix, p. 512, pl. lxiv, figs. 6-10.

One specimen of this well-known species occurs in our washings from Bed B. The view of the shell from the oral end bears a strong resemblance to the *N. prismatica* of Reuss—from the Chalk of Westphalia—the six costæ there visible giving the appearance of an hexagonal prism. The number of costæ is really twelve however, and, moreover, we quite agree with Brady in reckoning *N. prismatica* as a variety of *N. raphanus* not calling for a distinguishing name.

14. *Nodosaria obliqua* (Linné).

(Pl. II, Fig. 3.)

Nautilus obliqua, Linné, 1767, *Syst. Nat.*, 12th ed., p. 1163, 281; *Dentalina bifurcata*, d'Orb., *For. Foss. Vienne*, 1846, p. 56, pl. ii, figs. 38, 39; *Nodosaria obliqua*, Brady, 1884, *Rep. Chall.*, p. 513, pl. lxiv, figs. 20-22.

This form, widely diffused in recent seas and of common occurrence in the fossil condition, at least in Tertiary strata, occurs very rarely in Bed D, commonly in Bed C, and less frequently in Bed B.

15. *Nodosaria* (*Dentalina*) *communis*, d'Orbigny.

(Pl. II, Figs. 7, 9.)

Dentalina communis, d'Orb., 1840, *Mém. Soc. Géol. France*, vol. iv, p. 13, pl. i, fig. 4. *Nodosaria* (*D.*) *communis*, Brady, *Rep. Chall.*, 1884, vol. ix, p. 504, pl. lxii, figs. 19-22.

The specimens of this well-known shell, obtained from our Pegwell Bay washings are small, and confined to the upper part of Bed F, where they occur very rarely.

CRISTELLARIA, Lamarck.

Cristellariæ are the characteristic Foraminifera of the Thanet Sands at Pegwell Bay. They are far more abundant than any other "genus," and in Bed F the ensiform or "Marginuline" varieties are exceedingly abundant and very well grown.

The *quasi* generic term *Marginulina*, has been used by authors in a somewhat inexact manner, and, as Brady remarks,* the vague use of the term "has been a source of much confusion of nomenclature." Brady himself attempts to show that the term was intended by d'Orbigny to exclude the laterally compressed *Nodosarinæ*, which have commonly been referred to the genus. He says,† "The descriptive characters of the genus *Marginulina*, as furnished by d'Orbigny in the "Tableau Methodique," are brief and insufficient; but it is manifest from the various figures referred to in the enumeration of species that it was intended to include only the sub-cylindrical, as distinct from the compressed, forms of *Nodosarinæ*; and the fuller description subsequently given in the 'Vienna Basin' monograph, in which the globular shape of the segments is expressly mentioned, confirms this view."

We fear that the "intention" of d'Orbigny, in the direction indicated by Brady, is not so manifest as was supposed. In d'Orbigny's original description the marginuline shell is distinctly stated to have the form of a "curved scabbard" (*gaine arquée*), and this phrase is hardly consistent with the exclusion of shells showing lateral compression. Moreover, though it is true that in the description of the genus, as given in the "Vienna Basin" Monograph, the component chambers of the shell are said to be globular, and that the figures in Plate III of that work show that the transverse sections of the *final chambers* of the species figured are more or less circular in outline, yet the description given in the "Vienna Basin" memoir, which was published in 1846, appears verbatim in the "Craie Blanche" paper, which saw the light six years earlier; and the figures in Plate I of the earlier work show the *Marginulinæ* with chambers laterally compressed.

There can be no doubt either that other authors who have used the generic term in question have understood it to include shells showing a considerable amount of lateral compression. Jones and Parker, for instance, in their well-known papers on the nomenclature of the Foraminifera, published in *The Annals and*

* *Rep. Chall.*, vol. ix, p. 527.

† *Op cit.*, p. 526.

Magazine of Natural History, treat *Marginulina* as a quasi sub-genus of *Cristellaria*, and describe forms such as we figure on Plates I, III, and IV, as "marginuline cristellariae"; and again, in their paper on the Foraminifera, figured by Fichtel and Möll,* they describe the typical *Nautilus* (*Cristellaria*) *crepidula*, which is much compressed, as "a delicate, elongate, marginuline, flattened cristellaria." A further illustration of their use of the term is furnished by their *Marginulina lituus*, which we figure upon Pl. IV.

Some authors have attempted to limit the scope of the "genus" *Marginulina* by making the possession of a simple or a radiating aperture distinguishing features. Thus M. Berthelin† says: "Les vraies marginulines ont l'ouverture tubuleuse et non radiée, comme les nodosaires, auxquelles elles me paraîtraient plutôt se rapporter, tandis que les formes plus ou moins enroulées, douées d'une ouverture radiée, rentrent dans les Cristellaires." In the same manner M. Berthelin separates *Nodosaria* and *Dentalina*, the former term embracing the *Nodosaria* with tubular non-radiate apertures, and the latter comprising those with radiating apertures. But as Brady has well shown (*Report Chall.*, 1884, vol. ix, p. 443) a particular form of aperture is useless for classificatory purposes in the simple genus *Lagena*, and it is only necessary to look over a good collection of published figures—to say nothing of a wide series of actual specimens—to see that the radiating or non-radiating aperture is equally useless in the differentiation of *Nodosaria* and *Dentalina*, or *Marginulina* and *Cristellaria*.

It is, perhaps, worthy of remark that d'Orbigny (*For. Foss. Vienne*, 1846, p. 66), in distinguishing *Marginulina* from certain allied forms, laid stress upon the *prolongation* of the final chamber in which the aperture is situated, and upon the tendency which the earlier chambers show to a spiral form of growth. He also defined the position of the aperture as marginal, and placed on the convex side of the curved axis of the shell. We cannot help thinking, after comparing d'Orbigny's various drawings of *Marginulina*, that the typical *marginal* aperture is one situate in a prolongation of the final chamber, whose direction or axis is placed at a return angle with the convex curve of the shell. The combination of this character with that of the *tendency* to a spiral arrangement of the earlier chambers gives a more or less sigmoid curve to the shell; and it is interesting to notice that if this curvature were taken as a distinguishing feature, d'Orbigny's *modèle* No. 55 would satisfy the rule, as would also the *M. raphanus* of the "Tableau Méthodique," all the *Marginulina* figured in the "Craie Blanche" paper, and all, or nearly all, those figured in the "Vienna Basin" memoir.

* *Ann. Mag. Nat. Hist.*, 3rd ser., vol. v, p. 114.

† *Mém. Soc. Géol. France*, Sér. 3, Tom 1, 1880, p. 33.

We quite admit that even if thus restricted the genus must remain ill-defined, and, for ourselves, we should be content to see it discarded altogether, as is done by Goës, for instance. If it be retained for the sake of convenience in classification, we think it should be used less vaguely than it has been, and, at the same time, that its "characters" should not be so modified as to exclude the forms which, being among those first described, must be looked upon as typical of the genus.

CRISTELLARIA, Lamarck.

16. *Cristellaria fragraria* (Gümbel). Pl. II, Fig. 1.

An interesting example of the confusion in nomenclature caused by the indefinite position of the genus *Marginulina* is furnished by the case of the species commonly known as *Marginulina wetherellii*, Jones—the *Cristellaria wetherelli* (Jones) of the *Challenger* Report.

The name *Cristellaria wetherellii* was first given by Prof. Rupert Jones to a form which was described, but not figured, in the *Quart. Journ. Geol. Soc.*, vol. viii, 1852, p. 267. In the *Cat. Foss. For. Brit. Mus.*, 1882, p. 19, there is a record of a *Cristellaria italica*, Defrance, var. *wetherellii*, Jones, from the Thanet Sands, and for a description of the species the reader is referred to the description of *Cristellaria wetherellii* in the *Quart. Journ. Geol. Soc.* already referred to. We have the authority of Prof. Rupert Jones for saying that the reference to *Cr. italica* in the Museum Catalogue was incorrect, and there is no doubt that the form described in the *Quart. Journ. Geol. Soc.* in 1852, and recorded in the Museum Catalogue in 1882, from the Thanet Sands is one of the ensiform smooth *Cristellariæ*, so common in Bed F, and which we have referred to *C. crepidula* and its varieties.

The name *Marginulina wetherellii* was given by Prof. Rupert Jones in 1854 to a shell figured by Sowerby in 1840 in the *Trans. Geol. Soc.* for 1837, ser. 2, vol. v, p. 135, pl. ix, fig. 12, but there named "*Marginulina*" simply. The same form has been figured and described since by other authors under different names. We need only notice the name *Marginulina fragraria* given by Gümbel in 1868. (*Abh. m.-ph. Cl. k.-bayer. Ak. Wiss.* vol. x, p. 635, pl. i, fig. 58, a, b, c.)

Brady, in the *Challenger Report*, referred the species to the genus *Cristellaria*, and, if a large number of specimens are studied, especially if taken from a locality where the species occurs plentifully, we think it must be so referred.

This being so, the specific name *wetherellii* cannot stand, because it is already occupied, and *C. fragraria* (Gümbel) must be taken as the proper designation of the species.



CRISTELLARIA FRAGRARIA (GUMBEL)

A single specimen of *C. fragraria* occurs in our gatherings from the Pegwell Bay section, and that from Bed D.

The species is especially common in the London Clay, and Mr. C. D. Sherborn, who has devoted much time to the study of the form, has kindly placed at our disposal his MS. notes and numerous drawings. We are thus enabled to give a plate, illustrating some of the variations of the form, which was prepared by Mr. Sherborn some years since, but which has not hitherto been published. All the specimens there represented were from the London Clay; No. 1 from Chelsea, No. 13 from Islington, the rest from Piccadilly.

C. fragraria is essentially a decorated form of *C. crepidula*. There is considerable variation in the size of specimens from the same locality, and "in the relative development of the spiral and linear portions." The shorter specimens are sometimes rather stoutly built, and approach *C. platypleura* in contour. The ornamentation consists of tubercles and ridges variously disposed. The tubercles generally take the direction of the septal lines, while the ridges most frequently assume a longitudinal direction. Occasionally the longitudinal ridges are replaced by elongate tubercles; and less frequently the ridges themselves, whether transverse or longitudinal, are tuberculated. As a general rule the test of the longer specimens, while it is not cylindrical, shows no marked degree of compression, but Mr. Sherborn's drawings include a series of forms from an unnamed locality* which are excessively compressed, and which have the later chambers very much outspread. The ornamentation upon these forms is likewise very irregular, and sometimes almost wanting. They closely resemble *C. gemmata*, Brady, of the *Challenger Report*.

The *Challenger* specimens of *C. fragraria* were not perfect, and were obtained from Torres Strait, off Raine Island, at a depth of 155 fathoms, and off the coast of S. America, S.E. of Pernambuco, at a depth of 350 fathoms.

Save for the specimens collected by the *Challenger*, the species is, we believe, known with certainty only as a Tertiary fossil. As we have already stated, it is particularly abundant in the London Clay.

17. *Cristellaria crepidula* (Fichtel and Moll).

Pl. I, Figs. 1-21.

Nautilus crepidula, Fichtel and Moll, 1798. *Test. Micr.*, p. 107, pl. xix, figs. G-I.

Cristellaria recta, d'Orbigny, 1839. *Mem. Soc. Geol. France*, Tom. 2, p. 28, pl. ii, figs. 23-25.

Cristellaria crepidula, d'Orbigny, 1839. *Foram. Cuba*, p. 64, pl. viii, figs. 17 and 18.

* Mr. Sherborn tells us that these specimens were probably recent.

Marginulina gladius, Philippi, 1843. *Tertiär nordwest. Deutsch.*, p. 40, pl. i, fig. 37.

Cristellaria intermedia, Reuss, 1845. *Verstein böhm. Kreid*, part I., pp. 33, 108, pl. xiii, figs. 57 and 58; part II, pl. xxiv, figs. 50 and 51.

C. simplex, d'Orbigny, 1846. *For. Foss. Vienne*, p. 85, pl. iii, figs. 26-29.

C. cymboides, d'Orbigny, 1846. *Op. cit.*, p. 85, pl. iii, figs. 30 and 31.

C. wetherellii, Jones, 1852. *Quart. Journ. Geol. Soc*, vol. viii, p. 267.

C. protracta, Bornemann, 1854. *Lias von Gottingen*, p. 39, pl. iv, fig. 27.

C. varians, Bornemann, 1854. *Op. cit.*, p. 41, pl. iv, figs. 32-34.

C. subarcuatula, Williamson, 1858. *Rec. For. Gt. Brit.*, p. 29, pl. ii, figs. 56 and 57.

C. harpa, Reuss, 1860. *Sitz. k. Akad. Wiss. Wien*, xl, p. 211, pl. x, figs. 1 and 2.

C. crepidula, Parker and Jones, 1865. *Phil. Trans.*, p. 344, pl. xiii, figs. 15 and 16.

C. italica, DeFrance, var. *wetherellii*, Jones, 1882. *Cat. Foss. Foram. Brit. Mus.*, p. 19.

C. crepidula, Brady, 1884. *Rep. Chall.*, p. 542, pl. lxvii, figs. 17, 19, 20, and pl. lxviii, figs. 1 and 2.

Commenting on some recent *Cristellariæ* which present the characters of a group of figures in Von Schlicht's well-known work, Brady (*Chall. Rep.*, p. 536) expresses the opinion that "when the attenuated *Cristellariæ* of the Tertiary formations come to be critically studied as a whole, the number of species will be very greatly reduced." Parker and Jones had long previously expressed in effect the same view in their papers on the nomenclature of the Foraminifera already referred to; and in the papers on the variability of the Foraminifera as illustrated by the Cristellarians, Prof. Rupert Jones, and afterwards Prof. Rupert Jones and C. D. Sherborn have grouped the attenuated or ensiform varieties of *Cristellaria* round the form *Cristellaria crepidula* (F. and M.) The specimens under the consideration of these authors were in some cases recent, in others fossil; and the fossil specimens were derived from many localities and many horizons. In the last-mentioned paper, however, Messrs. Jones and Sherborn call attention specially to eight and a-half quarto plates in Von Schlicht's work, which contain 213 figures of the *Cristellariæ* alone, and they observe, "The most cursory examination of these plates will show the extremely close connection existing between all the forms; and having in hand the illustrations of so fine a series from *one* deposit, and therefore of so large a group of forms most probably living continuously in one

area, and under one set of conditions, we are enabled to see in a striking manner how greatly one form can and does pass into manifold varieties, and how difficult it is to recognise the limitation of species, and say where they begin and where they end."

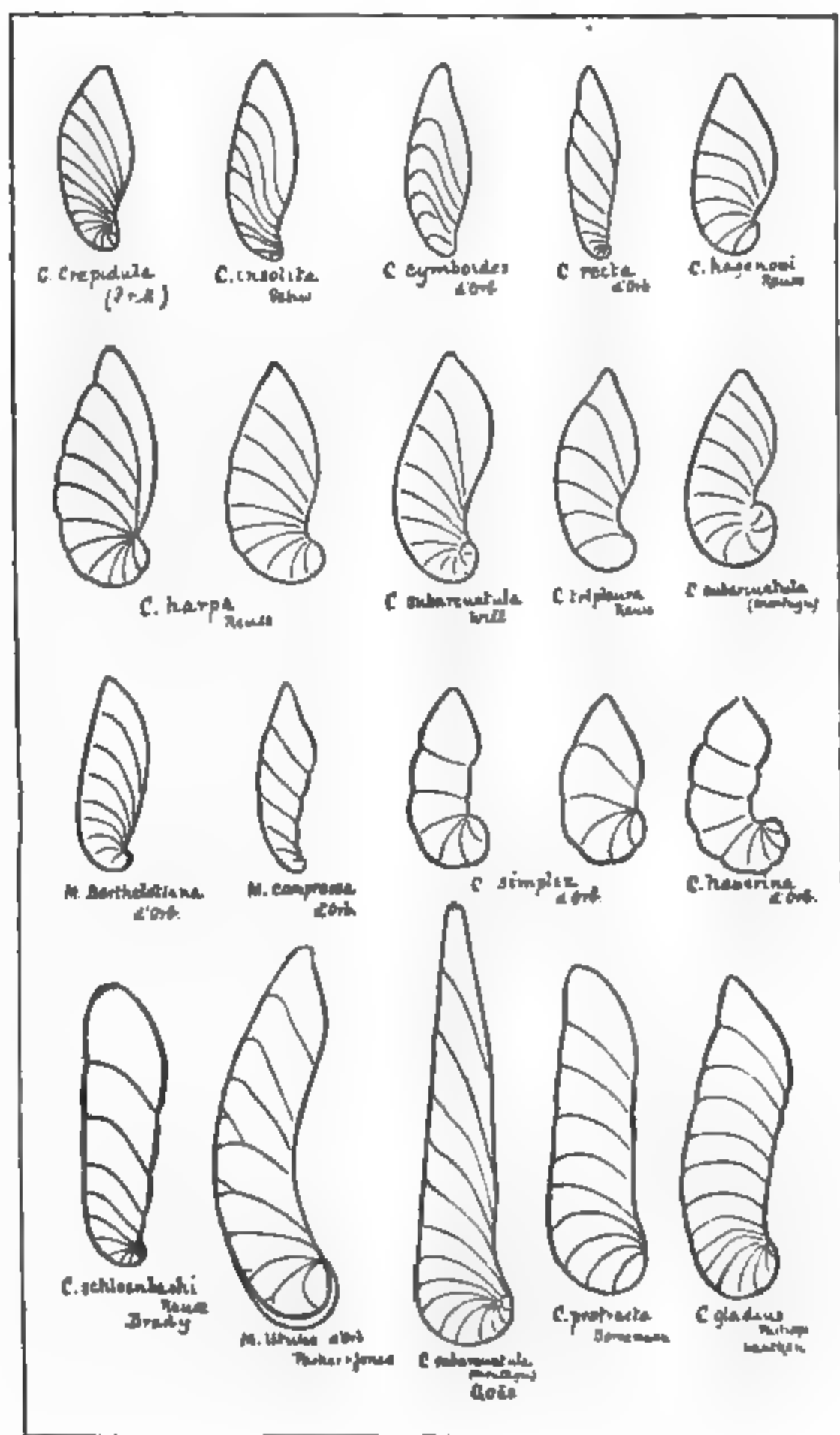
In the light of the foregoing remarks, the attenuated *Cristellaria* obtained from the Pegwell Bay Section of the Thanet Sands furnish points of great interest.

The forms collected by us are extremely variable in minor details, and at the same time they range themselves naturally round the typical *C. crepidula* (F. and M.). The extremes of variation are closely connected by intermediate links; and the fact that all the specimens come from the same handful of material makes it impossible to suppose that the varieties can be specifically distinct, or that the differences of contour can represent more than individual variation.

It will be seen from the figures which we give that if the attenuated forms be taken as a whole—and in the circumstances there seems to be no justification for dealing with them in any other way—they cannot really be separated from *C. crepidula*; and we may add that there is nothing in the original description of that species by Fichtel and Moll which would exclude them. Nevertheless, in the "explanation" of the Plate, we have retained as varietal names the names of the "species" to which the more distinct varieties have been assigned by different authors. As an interesting illustration of the propriety of placing these various forms under the same specific appellation, and that *C. crepidula*, we figure (Plates IV and V) two series of forms taken from various authors. The first series shows some twenty figures, rejoicing in different specific names, nearly all of which can be matched from our Pegwell Bay specimens. The second series comprises a number of forms of various authors, at least as variable as the forms in the previous series, and all referred to *C. crepidula*. It should be stated that, to make comparison more easy, we have turned the figures about in some instances so as to have all the forms face the same way, and sometimes we have relatively enlarged the figures to some degree.

As we have already observed, all these varieties of attenuated *Cristellaria* come from one portion of the Pegwell Bay Section, that which we have named Bed F, Specimen 14. In this bed they occur in great profusion; in the six-inch shell band of bed C. one or two of the varieties sparingly occur; in the other beds we have not met with them at all.

It becomes interesting to compare the other localities from which similar specimens, both recent and fossil, have been obtained. The type of the species was a recent shell, and came from the Mediterranean. Williamson's specimens of *C. subarcuatula* came from various parts of the British coasts. The *Challenger* specimens of *C. crepidula* were not numerous, and



VARIETIES OF ENSIFORM CRISTELLARIAE.

were for the most part obtained from comparatively shallow water; although at one locality in the South Atlantic the species was met with at a depth of 2,350 fathoms. None of the *Challenger* specimens, however, appear to have been of the extremely elongate type. Egger figures a variety strikingly like some of the Pegwell Bay specimens, and that was obtained from a depth of less than 500 fathoms. The specimens of *C. crepidula*, whose figures we have copied from Goës, were obtained from the Atlantic off the Azores, at depths of about 300 fathoms; while his *C. subarcuatula*, which we also figure, came from the North Atlantic, at a depth of about 300 fathoms. We may add that we have ourselves obtained large specimens almost indistinguishable from some of the elongate varieties of Pegwell Bay from material taken from the Indian Ocean between Zanzibar and the Seychelles by H.M.S. *Stork*, at a depth of 2,550 fathoms.

C. protracta of Bornemann comes from the Lias; *C. harpa* and *C. hagenowi* of Reuss from the Cretaceous beds of Westphalia; *C. recta* of d'Orbigny from the White Chalk of France; *C. cymboides*, *C. simplex*, and *C. hauerina*, of the same author, are from the Miocene of Vienna. British fossil specimens have been obtained from the Cretaceous beds, from the London Clay, and from other Tertiary Deposits.

18. *Cristellaria gibba*, d'Orb.

Pl. II, Figs. 5, 6.

Cristellaria gibba, d'Orb., 1839, *Foram. Cuba.*, p. 63, Pl. vii, figs. 20, 21; *C. gibba*, Brady, 1884, *Rep. Chall.*, vol. ix, p. 546. pl. lxix, figs. 8, 9.

This "species," which stands morphologically between the elongate compressed forms grouped round *C. crepidula* and the compact lenticular varieties which have their type in *C. rotulata*, has been found by us in one part only of the Pegwell Bay Section, viz., the 6-inch shell band of Bed C. There it occurs very commonly, and the individuals are rather large and well-grown.

19. *Cristellaria platypleura*, Jones. Pl. II, Figs. 2, 2A.

C. platypleura, Jones, 1852, Prestwich, *Quart. Journ. Geol. Soc.*, viii, p. 267, pl. xvi, fig. 12; *C. cultrata* (Montf.) (*platypleura*, Jones), Jones, 1882, *Cat. Foss. Foram. Brit. Mus.*, p. 19.

This form has, so far as we are aware, not been found elsewhere than in the Thanet Sands, although very close allies have been recorded from various fossil deposits and from several localities in recent seas. It is very common in Bed C at Pegwell, rare in Bed D, and very rare in Bed E.

20. *Cristellaria crassa*, d'Orbigny. Pl. I, Fig. 24.

Cristellaria crassa, d'Orb., 1846, *For. Foss. Vienne*, p. 90, pl. iv, figs. 1-3; *C. crassa*, Brady, 1884, *Rep. Chall.*, p. 549, pl. lxx, fig. 1.

We have referred the form figured as above to this species of d'Orbigny because it closely agrees with the description and figures given in the "Vienna Basin" Memoir. In the Thanet Beds of Pegwell Bay there can be no doubt that the form is a mere variety of *C. platypleura*, in company with which it sparingly occurs. Our specimens show a complete sequence from the smooth *C. crassa* to the *C. platypleura*, with strongly costulate sutures.

21. *Cristellaria arcuata*, d'Orbigny. Pl. I., Fig. 22.

Cristellaria arcuata, d'Orbigny, 1846, *For. Foss. Vienne*, p. 87, pl. iii, figs. 34-36.

Two small but perfect specimens of this form were found in our material from Bed E.

We have cut a considerable number of sections of the more common forms of *Cristellaria* from the Pegwell Bay Section. We have not been able to prepare a sufficient number to justify any general statement as to the internal structure; but it may be well to record that all the sections we have cut of *C. platypleura* and its cultrate allies show a megalospheric initial chamber. On the other hand, all our sections of *C. gibba* show the initial chamber to be microspheric; while in the ensiform varieties of *C. crepidula* the initial chambers are apparently indifferently megalospheric or microspheric.

SUB-FAMILY Polymorphininae.

POLYMORPHINA, d'Orbigny.22. *Polymorphina lactea* (Walker and Jacob).

Serpula lactea, Walker and Jacob, 1798, Adams's *Essays*, 2nd ed., p. 634, pl. xxiv, fig. 4; *Polymorphina lactea*, Brady, 1884, *Rep. Chall.*, vol. ix, p. 559, pl. lxxi, fig. 11.

23. *Polymorphina gibba*, d'Orbigny, var. *ampulla*,

Jones. Pl. II, Fig. 14.

Polymorphina ampulla, Jones, *Quart. Journ. Geol. Soc.*, 1852, vol. viii, p. 267, pl. xvi, fig. 14; *Polymorphina gibba*, d'Orb., var. *ampulla*, Jones, *Cat. Foss. Foram. Brit. Mus.*, 1882, p. 19.



24. **Polymorphina amygdaloides** (Reuss.). Pl. II, Fig. 18.

Globulina amygdaloides, Reuss, 1851, *Zeitsch. deutsch. geol. Gesell.*, vol. iii, p. 82, pl. vi, fig. 47; *Polymorphina amygdaloides*, Brady, 1884, *Rep. Chall.*, vol. ix, p. 560, pl. lxxi, fig. 13.

25. **Polymorphina communis** (d'Orb.). Pl. II, Fig. 13.

Guttulina communis, d'Orb., *Ann. Sci. Nat.*, vii, 1826, p. 266, pl. xii, figs. 1-4; *Polymorphina communis*, Brady, 1884, *Rep. Chall.*, p. 568, pl. lxxii, fig. 19.

26. **Polymorphina problema** (d'Orb.). Pl. II, Fig. 17.

Guttulina problema, d'Orb., 1826, *Ann. Sci. Nat.*, vii, p. 266, *Modèle* No. 61; *Polymorphina problema*, Brady, 1884, *Rep. Chall.*, p. 568, pl. lxxii, fig. 20, lxxiii, fig. 1.

27. **Polymorphina complanata** (d'Orb.). Pl. II, Fig. 16.

Polymorphina complanata, d'Orb., *For. Foss. Vienne*, 1846, p. 234, pl. xiii, figs. 25-30.

These *Polymorphinæ* are very rare in our Pegwell Bay material. They are also, as a rule, small. *P. communis* occurs in Beds B and E. The others are found only in the 6-inch shell band of Bed C.

28. **Polymorphina complanata** (d'Orb.), var. **striata**, nov.

Pl. II, Fig. 15.

Characters. Shell much compressed, sub-rhomboidal. Chambers elongate, oblique, and disposed in two regularly alternating series. Septal lines but slightly excavated. Surface ornamented with fine longitudinal parallel striæ. Aperture radiate.

One specimen of this well-marked variety occurs in our washings from the 6-inch shell band of Bed C.

FAMILY GLOBIGERINIDÆ.

29. **Globigerina bulloides** (d'Orb.). Pl. II, Fig. 19.

Globigerina bulloides, d'Orb., 1826, *Ann. Sci. Nat.*, vii, p. 277, No. 1, *Modèle* No. 76; *G. bulloides*, Brady, 1884, *Rep. Chall.*, ix, p. 593, pl. lxxix, figs. 1 and 2.

This cosmopolitan species occurs very sparingly in the Thanet Sands. We have small specimens from Beds C and F. In both the shell is rare, though less rare in Bed F than in Bed C.

30. *Pullenia sphæroides* (d'Orb.). Pl. II, Fig. 20.

Nonionina sphæroides, d'Orb., 1826, *Ann. Sci. Nat.*, vii, p. 293, No. 1, *Modèle* No. 43; *Pullenia sphæroides*, Brady, 1884, *Rep. Chall.*, p. 615, pl. lxxxiv, figs. 12, 13.

31. *Pullenia quinqueloba* (Reuss.). Pl. II, Fig. 21.

Nonionina quinqueloba, Reuss, 1851, *Zeitschr. d. Deutsch. Geol. Gesellsch.*, iii, p. 47, pl. v, fig. 31; *Pullenia quinqueloba*, Brady, 1884, *Rep. Chall.*, p. 617, pl. lxxxiv, figs. 14, 15.

These forms, like their ally, *Globigerina bulloides*, occur sporadically only in the Thanet Sands. *P. sphæroides* is found in our washings from Bed E only, and our specimens of *P. quinqueloba* come from Beds E and F.

FAMILY ROTALIDÆ.

SUB-FAMILY Rotalinæ.

32. *Truncatulina lobatula* (W. and J.). Pl. II, Fig. 24.

Nautilus lobatulus, Walker and Jacob, 1798, *Adams' Essays*, Kanmacher's Ed., p. 642, pl. xiv, fig. 36; *Truncatulina lobatula*, Brady, 1884, *Rep. Chall.*, p. 660, pl. xcii, fig. 10, etc.

33. *Truncatulina haidingerii* (d'Orb.).

Rotalina haidingerii, d'Orb., 1846, *For. Foss. Vienne*, p. 154, pl. vii, figs. 7-9; *Truncatulina haidingerii*, Brady, 1884, *Rep. Chall.*, p. 663, pl. xcv, fig. 7.

34. *Truncatulina ungeriana* (d'Orb.). Pl. II, Fig. 23.

Rotalina ungeriana, d'Orb., 1846, *For. Foss. Vienne*, p. 157, pl. viii, figs. 16-18; *Truncatulina ungeriana*, Brady, 1884, *Rep. Chall.*, p. 664, pl. xciv, fig. 9.

The *Truncatulinae* of the Thanet Sands call for little mention. They are nearly always small and poorly grown, and the specimens found are usually ill-preserved. *T. ungeriana* is found throughout the Thanet Beds of Pegwell Bay. It is met with commonly in Bed F, less commonly in Beds B and C, and more or less rarely in the intermediate Beds D. and E. *T. haidingerii* occurs very rarely (one specimen), in Bed E only. *T. lobatula* occurs in Beds B, C, D, very rarely in B and D, and rarely in C.

In the *Quart. Journ. Geol. Soc.*, vol. viii, 1852, p. 267, Pl. xvi, Fig. 13, Prof. Rupert Jones described and figured

Rosalina mariæ n.sp. from the Thanet Sands. The figure is, unfortunately, not a good one, and the figured specimen which is in the British Museum is not well preserved, so that it is rather difficult to make out exactly the distinctive characters of the species. In the *Cat. Foss. Foram. Brit. Mus.*, 1882, p. 19, Prof. Jones makes the species a variety of *Truncatulina lobatula*. We have carefully looked for *T. mariæ* in our washings, but the specimens which at first sight appear to possess the characters of that species are found, on further examination, to be *Truncatulina ungeriana* or *Anomalina grosserugosa*.

35. *Anomalina ammonoides* (Reuss.).

Rosalina ammonoides, Reuss, 1845, *Verstein. böhm. Kreid.*, Pt. I., p. 36, pl. xiii, fig. 66, pl. viii, fig. 53; *Anomalina ammonoides*, Brady, 1884, *Rep. Chall.*, p. 672, pl. xciv, figs. 2, 3.

36. *Anomalina grosserugosa* (Gümbel). Pl. II, Fig. 26.

Truncatulina grosserugosa, Gümbel, 1868, *Abhandl. d. k. bayer. Akad. Wiss.*, II cl., vol. x., p. 660, pl. ii, fig. 104; *Anomalina grosserugosa*, Brady, 1884, *Rep. Chall.*, p. 673, pl. xciv, figs. 4, 5.

Anomalina grosserugosa is one of the most common of the Thanet Sands Foraminifera. Its range extends throughout the Beds, but it is most common in Beds C and F. *A. ammonoides* occurs in our washings from Bed F only. The specimens are always small, and generally poorly grown and badly preserved.

37. *Pulvinulina menardii* (d'Orb.). Pl. II, Fig. 22.

Rotalia menardii, d'Orb., 1826, *Ann. Sci. Nat.*, vii, p. 273, No. 26, *Modèle* No. 10; *Pulvinulina menardii*, Brady, 1884, *Rep. Chall.*, p. 690, pl. ciii, figs. 1, 2.

38. *Pulvinulina elegans* (d'Orb.).

Rotalia (Turbinulina) elegans, d'Orb., 1826, *Ann. Sci. Nat.*, p. 276, No. 54; *Pulvinulina elegans*, Brady, 1884, *Rep. Chall.*, p. 699, pl. cv, figs. 4, 5, 6.

One small, but perfect and well-preserved, specimen of *P. menardii* occurs in our material from the 6-inch shell band of Bed C. *P. elegans* occurs in Beds C, E, and F, always very rarely. The specimens are also always small, and not very well preserved.

39. *Pulvinulina exigua* (Brady), var. *obtusa* nov.

Pl. II, Fig. 25.

Characters. Test free, rotaliform; both faces convex and generally equally so; composed of three convolutions, of which the outermost has usually five segments. Sutures non-limbate; marked on the superior face by thickened lines of opaque shell substance; on the inferior by slight depressions; periphery obtuse, and very rarely lobulated.

This is probably, next to *Bulimina elongata*, the most common Foraminifer of the Thanet Sands. It is met with in every division except Bed B, and in Bed F is very abundant. It differs from *P. exigua*, Brady (*Chall. Rep.*, p. 696, pl. ciii, 13, 14), chiefly in its obtuse periphery. This character may appear at first sight of little value, but we have carefully examined a large number of recent specimens of *P. exigua*, and we find that the acute lobulated periphery is remarkably constant, while the obtuse periphery and more compact habit are no less constant characters in the var. *obtusa* from the Thanet Sands. *P. exigua* is a deep water form. Of the thirty-four stations from which specimens were obtained by the *Challenger*, "twenty-five have depths exceeding 1,000 fathoms, and fourteen exceeding 2,000 fathoms" (*Rep. Chall.*, ix, p. 696).

40. *Rotalia beccarii* (Linné).

Nautilus beccarii, Linné, 1767, *Syst. Nat.*, 12th ed., p. 1162; *Rotalia beccarii*, Brady, 1884, *Rep. Chall.*, p. 704, pl. cvii, 2, 3. One small poor specimen of this very common form occurs in our washings from Bed F.

FAMILY NUMMULINIDÆ.

SUB-FAMILY Polystomellinæ.

41. *Nonionina depressula* (Walker and Jacob).

Nautilus depressulus, W. and J., 1798, Adam's *Essays*, Kanmacher's ed., p. 641, pl. xiv, fig. 33; *Nonionina depressula*, Brady, 1884, *Rep. Chall.*, p. 725, pl. cix, figs. 6, 7.

This form is represented in our washings by one small specimen from Bed B.

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IV.—TABLE SHOWING THE DISTRIBUTION OF THE FORAMINIFERA IN THE BEDS OF THE PEGWELL BAY SECTION.

L. large; M. middle-sized; S. small; R.L. rather large; V.S. very small; r. rare; c. common; r.r. rather rare; r.c. rather common; v.r. very rare; v.c. very common.

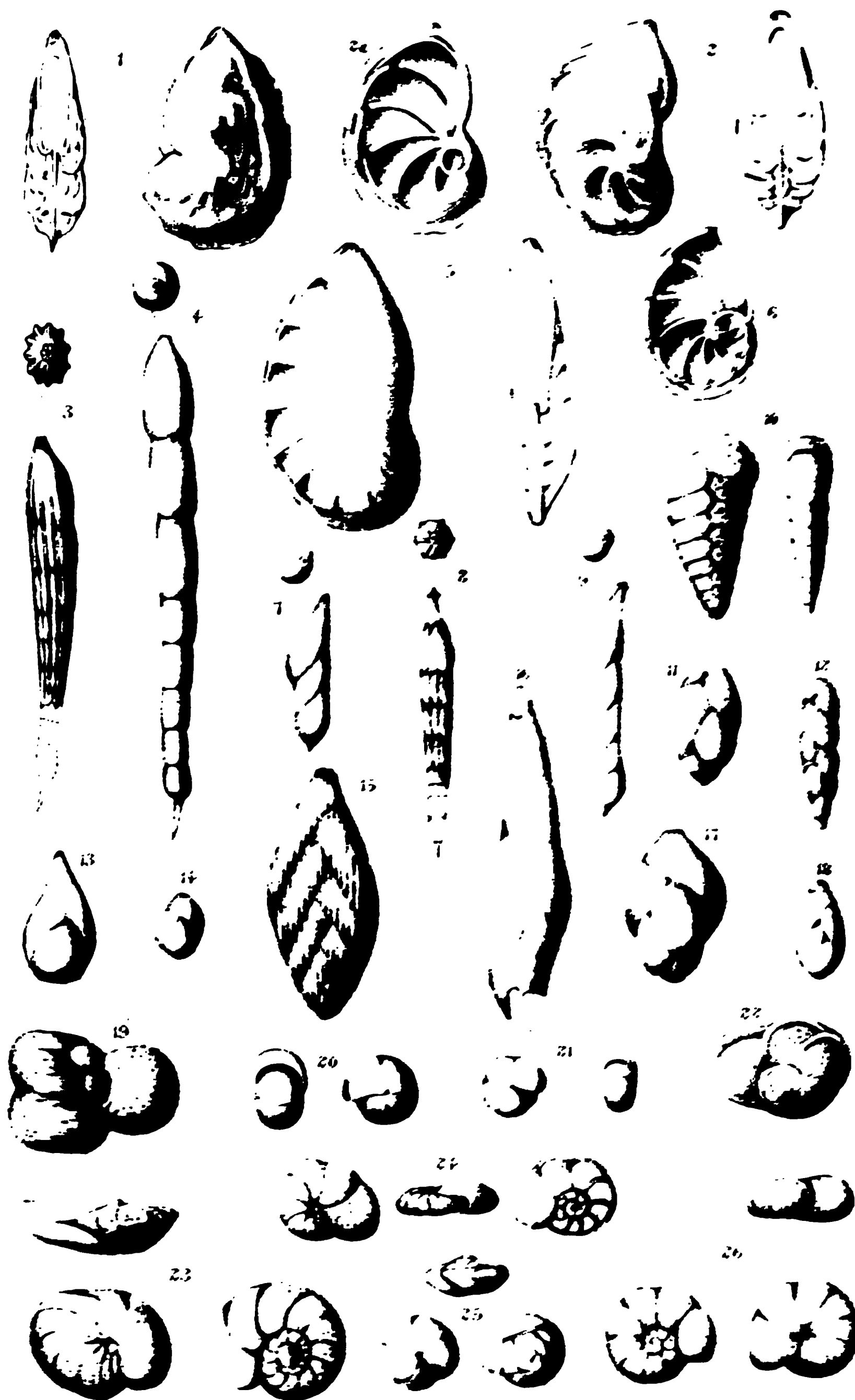
No.	GENERA, SPECIES, AND VARIETIES.	DRIFT. A	THANET SANDS.					FLINT BED. G	
			B	C	D	E	F		
1	<i>Astrorhiza arenaria</i> , Norman ...	M. r.c.							
2	<i>Ammodiscus incertus</i> (d'Orb.), var.								
3	<i>Textilaria globulosa</i> , Ehr.								
4	" <i>sagittula</i> , Defr.								
5	<i>Bulimina ovata</i> , d'Orb.	S. v.r.	M. v.c.	M. c.	M. r.	M. r.	M. r.	S. r.r.	S. v.r.
6	" <i>elongata</i> , d'Orb.	S. v.r.	M. v.r.	M. v.r.	M. r.	M. r.	M. c	M. v.c.	V.S. v.r.
7	" <i>pirula</i> , d'Orb.								
8	<i>Bolivina cenariensis</i> (Costa)								
9	<i>Chilostomella ovoidea</i> , Reuss								
10	<i>Lagena apiculata</i> , Reuss								
11	" <i>laevis</i> (Montag.)								
12	" <i>laevigata</i> (Reuss)								
13	" <i>reticulata</i> , Macgillivray								
14	" <i>marginala</i> (W. & B.) ...								
15	<i>Nodosaria farcimen</i> (Soldani)		S. v.r.	V.S. v.r.					
16	" <i>raphanus</i> (Linné) ...								
17	" <i>obliqua</i> (Linné) ...		S. v.r.		S. v.r.				
18	(<i>D.</i>) <i>communis</i> , d'Orb.		M. r.r.	S. c.	S. v.r.				
19	<i>Cristellaria fragraria</i> (Gümbel)								
20	" <i>crepidula</i> (F. and M.), var. <i>cymboides</i> , d'Orb.								
21	" " " <i>recta</i> , d'Orb.								
22	" " " <i>simplex</i> , d'Orb.								
23	" " " <i>gladius</i> (Philippi)								
24	" " " <i>varians</i> , Born.								
25	" " " <i>protracta</i> , Born.								

PLATE I.

Fig. 1-3	<i>Cristellaria crepidula</i> (F. & M.),	var. <i>cymboides</i> , d'Orb.	×	18, p. 40
" 4	"	var. <i>recta</i> , d'Orb.	×	14, p. 39
" 5, 23	"	var. <i>simplex</i> , d'Orb.	×	14, p. 40
" 6, 9, 16	"	var. <i>gladius</i> , Philippi	×	14, p. 40
" 7, 10	"	var. <i>varians</i> ,		
		Bornemann	×	14, p. 40
" 8, 13-15	"	var. <i>protracta</i> ,		
		Bornemann	×	14, p. 40
" 11	"	var. <i>intermedia</i> , Reuss	×	14, p. 40
" 12, 18-21	"	var. <i>harpa</i> , Reuss	×	14, p. 40
" 17	"	var. <i>subarcuatula</i> ,		
		Williamson	×	14, p. 40
" 22	"	<i>arcuata</i> , d'Orb.	.	.
" 24	"	<i>crassa</i> , d'Orb.	.	.
			×	30, p. 45
			×	30, p. 45

PLATE II.

Fig. 1	<i>Cristellaria fragraria</i> (Gümbel)	.	.	.	×	18, p. 38
" 2	" <i>platypleura</i> , Jones	.	.	.	×	20, p. 44
" 3	<i>Nodosaria (Dentalina) obliqua</i> (Linné)	.	.	.	×	20, p. 35
" 4	<i>Nodosaria (D.) farcimen</i> (Soldani)	.	.	.	×	12, p. 35
" 5	<i>Cristellaria gibba</i> , d'Orb.	.	.	.	×	25, p. 44
" 6	" " " (section)	.	.	.	×	14, p. 45
" 7, 9	<i>Nodosaria (D.) communis</i> , d'Orb.	.	.	.	×	35, p. 35
" 8	" <i>raphanus</i> (Linné)	.	.	.	×	35, p. 35
" 10	<i>Textilaria sagittula</i> , Defrance	.	.	.	×	30, p. 31
" 11	<i>Bulimina ovata</i> , d'Orb.	.	.	.	×	35, p. 32
" 12	" <i>elongata</i> , d'Orb.	.	.	.	×	50, p. 32
" 13	<i>Polymorphina communis</i> , d'Orb.	.	.	.	×	25, p. 46
" 14	" <i>gibba</i> , d'Orb., var. <i>ampulla</i> , Jones	.	.	.	×	25, p. 45
" 15	" <i>complanata</i> , d'Orb., var. <i>striata</i> , nov.	.	.	.	×	25, p. 46
" 16	" " " (abnormal)	.	.	.	×	25, p. 46
" 17	" <i>problema</i> , d'Orb.	.	.	.	×	25, p. 46
" 18	" <i>amygdaloides</i> , Reuss	.	.	.	×	25, p. 46
" 19	<i>Globigerina bulloides</i> , d'Orb.	.	.	.	×	30, p. 46
" 20	<i>Pullenia sphaeroides</i> , d'Orb.	.	.	.	×	30, p. 47
" 21	" <i>quinqueloba</i> , Reuss	.	.	.	×	30, p. 47
" 22	<i>Pulvinulina menardii</i> (d'Orb.)	.	.	.	×	25, p. 48
" 23	<i>Truncatulina ungeriana</i> (d'Orb.)	.	.	.	×	30, p. 47
" 24	" <i>lobatula</i> (W. & J.)	.	.	.	×	30, p. 47
" 25	<i>Pulvinulina exigua</i> , Brady, var. <i>obtusa</i> , nov.	.	.	.	×	30, p. 49
" 26	<i>Anomalina grosserugosa</i> (Gümbel)	.	.	.	×	30, p. 48



H. W. Burrows
P. H. Huxley del. et sculp.

See also Plate XV of same volume

FORAMINIFERA
THANET BEDS. PEGWELL BAY.

ORDINARY MEETING.

FRIDAY, NOVEMBER 6TH, 1896.

The President, E. T. NEWTON, F.R.S., in the Chair.

Messrs. Thomas Leslie and Edwin Sloper were elected Members of the Association.

A conversational evening was held, and the following is a list of the exhibitors and their exhibits :—

The DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY :—

General Geological Survey Map of England and Wales (Index Maps, 4 miles to 1 inch), Sheets 2, 4, 5, 8 and 10, being advance copies of the Sheets completing this Map.

Mr. E. T. NEWTON, F.R.S. :—Four cases of Flint and other Implements from various localities.

Mr. J. D. HARDY :—Model and Photograph of Mare Crisium in the Moon.

Rev. Prof. J. F. BLAKE :—Implements of Agate from Kathi-
awar ; “Golden Oolite” from Cutch.

A. MORLEY DAVIES :—*Echinocaris whidbornei* from Barnstaple, and other fossils.

Miss RAISIN :—Granites from the Vosges ; Agates and Pyromerides from N. Wales ; Dolomitic Conglomerates from the Mendips.

Prof. T. G. BONNEY, M.A., D.Sc., F.R.S. :—Glaciated Permo-Carboniferous Rocks from S. Australia ; Riebeckite and Felsite from Drift near Dublin ; Schists from the Alps.

Mr. FREDK. CHAPMAN :—Mollusca from the Tufa deposits of Blashenwell.

Mrs. ROBERT ELLIOTT :—Large series of Flint Implements (Neolithic) from Warren Hill, Suffolk.

Mr. BENJAMIN HARRISON :—Series of Eolithic Implements from the Plateau Gravels of Kent ; exhibited and explained by Dr. Frank Corner.

Mr. J. SLADE :—Cone in cone from Merthyr ; Quartz and Dolomite with Millerite ; Beryl in quartz from Sweden.

Mr. DIBLEY :—Ptychodus from the Chalk of Burham.

Mr. A. E. SALTER :—Samples of Gravels from Devon and Dorset ; Radiolarian Chert, etc.

Mr. H. W. MONCKTON :—Series of Photographs of geological localities visited by the Association.

Dr. A. MITCHELL :—A series of pieces of granite, all of peculiar shape, and apparently worked and used as stone weapons ; from a gravel deposit, Cape Breton, Nova Scotia.

Mr. COOMARA-SWAMY :—Photographs taken during Excursions of the Association.

Mr. G. G. F. BROWN :—Fossils from the Oldhaven Beds, Beckenham ; and from the Upper Chalk of Kenley.

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- Mr. HY. PRESTON :—Upper Lias Gasteropoda from Grantham.
 Mr. GWINNELL :—Series of Garnets and Zeolites, and other Mineral Specimens.
 Mr. G. E. W. COLENUTT :—*Clupea vectensis*, and Reptilian remains from the Oligocene of the Isle of Wight.
 Mr. BEDFORD MCNEILL :—Fossils collected on the Excursions.
 Mr. H. A. ALLEN :—Crystal of Corundum.
 Mr. UPFIELD GREEN :—Series of Devonian fossils from the Rhine Provinces.
 Mr. R. S. HERRIES :—Large series of Ammonites from the Lias of Yorkshire.
 Mr. F. A. BATHER :—*Uintacrinus* from Westphalia.
 Dr. A. W. ROWE :—A series of remains of *Uintacrinus* from the Chalk of Margate.
 Miss FOLEY :—Rock specimens from the Rhine Provinces.
 Mr. JOHN TERVET :—Plant remains from the Carboniferous of Lothian ; a diagrammatic classification of Igneous Rocks.
 Mr. W. W. WATTS :—A series of Albums of Photographs preserved by the Geological Photographs Committee of the British Association.
 Mr. GEORGE SMITH :—Rock sections under the microscope.

ORDINARY MEETING.

FRIDAY, DECEMBER 4TH, 1896.

The President, E. T. NEWTON, F.R.S., in the Chair.

The following were elected Members of the Association :
 F. G. Collins, W. Penhale, Miss Partridge, W. A. Brend, E. Marsh, G. A. Stonier, W. E. Harrison, and W. T. Tucker.

A paper was read "On the Foraminifera of the Thanet Beds of Pegwell Bay," by R. Holland and H. W. Burrows, A.R.I.B.A.

Mr. Newton exhibited specimens of *Terebratula grandis* from the Crag of Sudbourne.

Mr. Upfield Green exhibited some Cornish Elvans.

ORDINARY MEETING.

FRIDAY, JANUARY 1ST, 1897.

The President, E. T. NEWTON, F.R.S., in the Chair.

The following were elected Members of the Association :
 H. E. Cooke, E. E. L. Dixon, R. Tervet, F. Todd, T. Parker, and L. H. Cooke.

Mr. A. E. Salter and Dr. E. Johnson were elected auditors.

A paper was read by Professor T. G. Bonney, F.R.S., "On the Petrology and Physical History of the Alps."

ANNUAL GENERAL MEETING.

FEBRUARY 5TH, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

Messrs. G. E. Dibley and H. S. Kennard were appointed Scrutineers of the ballot.

The following Report of the Council for the year 1896 was then read :—

THE numerical strength of the Association on the 31st of December, 1896, was as follows :—

Honorary Members	15
Ordinary Members—	
<i>a.</i> Life Members (Compounded)	163
<i>b.</i> Old Country Members (5s. Annual Subscription)	7
<i>c.</i> Other Members (10s. Annual Subscription)	348
	<hr/>
Total	533

During the year thirty new members were elected, of whom two subsequently withdrew. The Council regrets that the Association lost seven members by death : Sir Joseph Prestwich, Prof. A. H. Green, Capt. Marshall Hall, Wm. Brockbank, G. P. Cochrane, Dr. A. T. Brett, Miss E. Faust. Sir Joseph Prestwich, the Nestor of British geology, had been for ten years an honorary member of the Association ; although his advanced age prevented his attendance at your meetings, nevertheless many of you have pleasant recollections of visiting him at his hospitable home at Shoreham, near Sevenoaks, while he will be gratefully remembered by his bequest of a set of the Palæontographical Society's monographs to your Library. Prof. Green, who was for many years an officer of the Geological Survey, and afterwards succeeded Professor Prestwich as Professor of Geology at Oxford, will live in your memories chiefly by his *Memoirs on the Yorkshire Coal-Field*, and his *Physical Geology*, which will stand for all time as an able exposition of dynamical geology. Capt. Marshall Hall was a well-known figure at your meetings, and had but shortly before his death been labouring to collect information upon glacial geology, for which his long experience as an Alpine climber had especially fitted him. Dr. Brett was a most regular attendant at your excursions, especially the Long Excursion. His familiar form and voice, and kind, genial face will be much missed by his many friends.

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[illegible]

* This does not include a sum of £17 16s. 8d. due to the Printers for the Index, etc., to Vol. XIV.

We have compared the above account with the vouchers and find it to be correct

We have also verified the investment of £820 16s. 10d. Nottingham Corporation Stock.

January 13th, 1897.

A. F. SALTER,
EDWARD JOHNSON, }
Auditors.

The income of the Association for 1896, omitting that for the *Record of Excursions* and *Paris Basin*, was £251 7s. 7d., a slight increase on last year's figures, while the expenditure was £250 1s. 7d, which is considerably in excess of last year. This amount, however, includes the sum of £8 15s. for the purchase of the new lantern, which is really in the nature of an investment, and will, it is hoped, materially reduce next year the item of attendance, etc., in connection with the evening meetings, on which the principal increase in expenditure has taken place. This is due to the fact that the lantern was used on twice as many evenings as the year before, all of which, except one, were occasions before our new lantern came into use. It is believed, however, that these illustrative evenings are much appreciated, and, as has been pointed out, the expense will be much diminished by using our own apparatus in future. It will be seen that a sum of £17 16s. 8d. (which has since been paid) was due to the printers for the Index, etc., of Volume XIV. The balance carried forward, £26 1s. 10d., was more than enough to have paid this account if it had come in in time, but it was not as a matter of fact included in the estimates for 1896, as at the time they were prepared the Editor expected to bring out the new Index, etc., with Part I of the new volume.

During the year the usual five numbers of PROCEEDINGS have been published, consisting of 232 pages of text, with eleven plates and thirty-four other illustrations. You have to thank the authors contributing to your PROCEEDINGS, even more than usual, for enabling this exceptional number of plates to be published. You are indebted to your late President, General McMahon, for Plates VIII, IX, and X, illustrating his presidential address; to Mr. W. H. Hudleston for the map of India (Plate VII) and the other illustrations to his paper; to Mr. Monckton for Plate XI; and to Mr. Nicol Brown for the illustrations to his paper. With the November number were issued the Title-Pages, Contents, and Index to Vol. XIV, which is thus completed.

In addition to the before-mentioned bequest by Sir Joseph Prestwich of a complete set of the annual volumes of the monographs of the Palæontographical Society, the Library has continued to increase, mainly by the addition of the publications of other Societies. The long time during which the binding of serials was allowed to get into arrear has led to many of the sets becoming defective. Much of the arrear of binding has now been made up, and it is hoped that the generosity of other Societies will enable many of the defective sets to be completed.

A new catalogue of the books in the Library has been prepared, and will be printed shortly.

The fact that the Library of the Association is not, under present circumstances, as useful to the Members as it ought to be has long been felt by the Council. The authorities of University

College have always readily granted to the Association such facilities as are in their power, but it is impossible that, while the Library remains where it is, such constant access to the books can be obtained as can alone render the Library of real utility to the Members at large. With this aim in view, and with the object at the same time of retaining to the Association the property in and the control over their Library, Mr. George Potter, who was one of the Founders of the Association, and has devoted considerable attention to this subject, moved the Resolution printed below at a very full meeting of the Council on December 4th. The Resolution was seconded by Miss Raisin and carried unanimously, and was as follows :

“That the Trustees of the Geologists’ Association be empowered to enter into an agreement with the Public Library Commissioners of the Parish of St. Martin-in-the-Fields to deposit the Library of the Geologists’ Association for five years on loan in the Reference Library of the said Commissioners at Charing Cross ; the condition of such deposit being that the Members of the Association shall have the right of access to, and subject to the Library Regulations of the Association, of borrowing the books, pamphlets, etc., at any time that the Library of St. Martin is open to the public, the books, etc., being available for reference only to non-members of the Association ; and that an honorarium of a year be paid by the Association to the Librarian of St. Martin Public Library ; and that such agreement be renewed at the end of such period of five years, unless either party shall have given notice to the contrary twelve months before the expiration of such period.”

If the contemplated arrangement can be carried out, the central position of St. Martin, combined with the fact that the Library will be practically at all times accessible to the Members, will, it is thought, enable the Association for the first time to fully enjoy the use of their Library, while it will remain as much the property of the Association as hitherto.*

In the early days of the Association a small collection of geological interest was brought together, but as it was impossible to duly care for and attend to the specimens, your Council, acting under the old Byelaw xviii, removed in 1892 certain fragile specimens to the British Museum and to the Museum of Practical Geology. The remainder were stowed away again until 1894, when a report upon them was obtained and considered, and finally, in 1895, it was decided by the Council, that for the better preservation and usefulness of the specimens they should be presented to other institutions. This has now been accomplished, and a selection was first taken by the

* Such an agreement has been signed and sealed, and arrangements are now proceeding to carry it into effect.—[C. DAVIES SHERBORN, Hon. Sec., May 7th, 1897.]

authorities of University College; certain crinoids were selected by the British Museum, and the remaining specimens were given to the Whitechapel Free Library.

The following is a list of the papers read at the evening meetings:

"On the Lake-basins of Lakeland," by J. E. MARR, F.R.S.

"On some Structural Characters of the Granite of the Himalayas," being the address of the retiring President, GENERAL MCMAHON, F.G.S.

"Pebbly Gravel from Goring Gap to the Norfolk Coast," by A. E. SALTER, B.Sc., F.G.S.

"Some Pleistocene Ostracoda from Fulham," by FREDK. CHAPMAN, F.R.M.S.

"On the Physical Geology of Purbeck," by AUBREY STRAHAN, F.G.S.

"On the Brachiopoda of the Skiddaw Slates," by J. POSTLETHWAITE, F.G.S.

"On the Palæozoic Rocks of West Somerset and North Devon," by Dr. HENRY HICKS, F.R.S., Pres. G.S., with an appendix "On the Fossils of the District," by Rev. G. F. WHIDBORNE, F.G.S.

"Notes on the Trias, Rhætic, and Lias of West Somerset," by the Rev. H. H. WINWOOD, F.G.S.

"On the Foraminifera of the Thanet Sand of Pegwell Bay," by H. W. BURROWS, A.R.I.B.A., and RICHARD HOLLAND.

A lecture was delivered by Prof. JOHN MILNE, F.R.S., on "Bradyseisms, Earthquakes, and other Movements of the Earth's Crust," on June 5th; and a demonstration with the lantern was given on April 10th by W. F. GWINNELL, F.G.S. and HENRY PRESTON, F.G.S., of photographs taken during the excursions of the Association.

Your thanks are due to all these gentlemen.

A conversazione was held in November, when many objects of geological interest were exhibited by members of the Association. A full account will be found in the PROCEEDINGS.

The following Museums were visited in 1896:

March 14th.—The Geological Galleries of the British Museum (Natural History), Cromwell Road, when a demonstration on Fossil Fishes was given by Mr. A. SMITH WOODWARD, F.L.S., F.G.S.

May 9th.—The Chingford Museum, at Queen Elizabeth's Hunting Lodge, Chingford.

June 13th.—The Reading Museum.

July 26th.—The Museum of the Somersetshire Archæological and Natural History Society.

The following is a list of the excursions made during the past year. Detailed reports will be found in parts 8 and 10 of the PROCEEDINGS, vol xiv:

DATE.	PLACE.	DIRECTORS.
March 28th.	Galley Hill, near Northfleet, and Swanscomb Hill.	The President (E. T. Newton, F.R.S.), F. C. J. Spurrell, F.G.S., and H. Stopes.
April 3rd to 7th (Easter).	Swanage, Corfe Castle, Kimeridge, etc.	W. H. Huddleston, F.R.S., Rev. Owen L. Mansel, and H. W. Monckton, F.G.S.

DATE.	PLACE.	DIRECTORS.
April 18th.	The Zoological Gardens.	The President (E. T. Newton, F.R.S.), and F. E. Beddard, F.R.S.
April 25th.	Hendon.	H. Hicks, M.D., F.R.S., Pres. Geol. Soc.
May 2nd (whole day).	Dorking and Leith Hill.	Thos. Leighton, F.G.S.
May 9th.	Chingford and Epping Forest.	T. V. Holmes, F.G.S.
May 23rd to 26th (Whitsuntide).	Chippenham, Kellaways, Calne and Corsham.	Rev. H. H. Winwood, M.A., F.G.S., and H. B. Woodward, F.G.S.
June 6th (whole day).	Tattingstone Crag District of Suffolk.	The President (E. T. Newton, F.R.S.), and E. P. Ridley F.G.S.
June 13th.	Reading.	J. H. Blake, F.G.S., and H. W. Monckton, F.G.S.
June 20th.	Hitchin.	W. Hill, F.G.S., and H. W. Monckton, F.G.S.
July 4th.	Potter's Bar and Hatfield.	A. E. Salter, B.Sc., F.G.S.
July 11th (whole day).	New Railway, Catesby, Northants.	Beeby Thomson, F.C.S., F.G.S.
July 18th (whole day).	New Railway, Nottingham and Leicester.	G. Elmsley Coke (late Lieut. R. N.), Prof. J. W. Carr, M.A., F.G.S., and W. W. Watts, M.A., F.G.S.
July 27th to August 1st (Long Excursion).	West Somerset and North Devon.	H. Hicks, M.D., F.R.S., Pres. G.S., Rev. H. H. Winwood, M.A., F.G.S., and J. G. Hamling, F.G.S.

The interest of members in the excursions of the Association during the past year has been fully maintained.

Your thanks are due to the directors of the excursions, also to the following ladies and gentlemen for assistance and hospitality :

Mr. J. Hoyle, and Mr. and Mrs. Stopes, at Swanscomb ; Mr. W. Brindley, F.G.S., at Swanage ; Dr. and Mrs. Hicks, at Hendon ; Mr. William Cole, F.L.S., at Chingford ; Mr. H. Herbert Smith, at Calne ; Mr. George Hancock, at Corsham ; Mr. Caleb Webber, at Kellaways ; Mr. Thos. Holloway, at Chippenham ; Mr. W. Keeble and Mr. Cuthbert, at Tattingstone ; Messrs. Sir Douglas and Francis Fox, Mr. D. L. Hutchison, Messrs. Oliver & Co., and Mr. H. A. Attenborough, at Catesby ; Mr. E. Parry, Mr. H. Lovatt, and Messrs. Logan and Hemmingway, on July 18th ; and to Sir A. Acland Hood, Bart., the directors of the North Devon Athenæum, and Mr. W. Bidgood, on the Long Excursion, as well as to the Council of the Zoological Society for free admission to their gardens on April 18th.

Your thanks are also due to Sir Archibald Geikie, D.Sc., D.C.L., LL.D., F.R.S., Director General of the Geological Survey, for the presentation of sheets 21, 26, 27, of the old edition, and of sheets 329, 342, 343 of the new edition of the Geological Map of England, and of sheet 12 of the Index Map of England geologically coloured.

As mentioned in the last annual report, it was felt that some division of labour in the management and arrangement of the excursions of the Association was very necessary, and the work during the past year has accordingly been in the hands of the following committee: H. W. Monckton (chairman), H. A. Allen, R. S. Herries, T. Leighton, E. P. Ridley, W. P. D. Stebbing, and A. C. Young.

Your thanks are due to the members of this committee for the trouble they have taken and for the able way in which they have carried out the business arrangements, upon which the success of the excursions so largely depends; and it is recommended that this committee be reappointed as soon as the new Council meets.

Your thanks are due to the Council of University College for the continued advantages they offer you in the use of rooms, and to Mr. Horsburgh, the Secretary to the College, for his courtesy and assistance.

There are many changes in your House List. Dr. G. J. Hinde and Mr. T. V. Holmes retire from the list of Vice-Presidents and from the Council. Mr. Morley Davies retires from the Editorship of your PROCEEDINGS. Miss Raisin, Mr. A. C. Young, and Mr. B. B. Woodward retire from your Council. Your thanks are due to all of these for the assistance they have rendered in carrying out the work of the Association, and more especially to Mr. Morley Davies, who has edited your PROCEEDINGS for four years, carrying out a difficult and onerous task with energy, punctuality, and success. The presence of a lady representative upon the Council has proved so advantageous in the past that it is hoped the vacancy caused by the retirement of Miss Raisin will be again filled by the election of a lady member.

Finally, your Council submits the name of Professor T. G. Bonney, to whom geological science generally and yourselves in particular are so much indebted, as an honorary member.

The names of those suggested by your Council to fill the vacant offices will be found on the ballot paper.

On the motion of Dr. HENRY WOODWARD, seconded by Mr. R. ELLIOTT, the Report was adopted as the Annual Report of the Association.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:

PRESIDENT :

E. T. Newton, F.R.S.

VICE-PRESIDENTS :

Prof. T. G. Bonney, F.R.S.
 Thomas Leighton, F.G.S.

Lieut.-Gen. C. A. McMahon, F.G.S.
 George Potter, F.R.M.S.

TREASURER :

R. S. Herries, F.G.S.

SECRETARY :

C. Davies Sherborn, F.G.S.

EXCURSION SECRETARY :

Horace W. Monckton, F.L.S., F.G.S.

EDITOR :

H. A. Allen, F.G.S.

LIBRARIAN :

Wheatley J. Atkinson, F.G.S.

OTHER MEMBERS OF COUNCIL :

H. W. Burrows, A.R.I.B.A.
 Geo. C. Crick, A.R.S.M., F.G.S.
 A. Morley Davies, B.Sc., F.G.S.
 Henry Fleck.
 Miss Mary C. Foley, B.Sc.
 J. D. Hardy, F.R.M.S.

John Hopkinson, F.L.S., F.G.S.
 Prof. Raphael Meldola, F.R.S.
 F. W. Rudler, F.G.S.
 A. E. Salter, B.Sc.
 W. W. Watts, M.A., F.G.S.
 Wm. Whitaker, F.R.S.

On the motion of Mr. RICHARD HOLLAND, seconded by Colonel STIFFE, the thanks of the Association were unanimously voted to the officers and members of Council retiring from office, to the auditors, and to the scrutineers.

The President then delivered his annual address, entitled "On the Evidence for the Existence of Man in the Tertiary Period."

On the motion of Mr. WM. WHITAKER, seconded by Dr. HENRY WOODWARD, it was unanimously resolved that the President's address be printed in full.

This terminated the Annual Meeting.

THE EVIDENCE FOR THE EXISTENCE OF MAN IN THE TERTIARY PERIOD.

By E. T. NEWTON, F.R.S., F.Z.S., F.G.S.

[*Being the Presidential Address delivered February 5th, 1897.*]

[T was the late Professor Agassiz who said that “whenever a new and startling fact is brought to light in science, people first say, ‘it is not true,’ then that ‘it is contrary to religion,’ and lastly ‘that everybody knew it before.’”

Flint implements have certainly been no exception to this rule, as we all know. It is more than two centuries since the first palæolithic flint implement was found in the gravel in Gray’s Inn Lane, London (1690), and just over 100 years since many others were found at Hoxne in Suffolk (1795), but the importance of these discoveries was not appreciated until many years later.

I may say in passing that my colleague, Mr. Clement Reid, has recently* done an admirable piece of work in determining the relation which the Hoxne Palæolithic deposit bears to the Boulder Clay.

It is now fifty years since M. Boucher de Perthes† first published his account of the flint implements found, with remains of Mammoth and other extinct mammalia, in the gravels of the valley of the Somme, he believing the implements to have been made by man. It was, however, many years before geologists were inclined to accept his conclusions.

In the year 1858 the discovery of implements in Brixham Cave, made by Falconer, Prestwich, and Pengelly, induced Dr. Falconer to visit the collection of M. Boucher de Perthes, and in the same year Sir Joseph Prestwich, accompanied by Sir John Evans, went to the valley of the Somme, and was satisfied that the implements found there in the river gravels were, like those of the caves, of human workmanship and contemporaneous with the lower gravels and with the Mammoth. This verification of earlier discoveries was made known to the scientific world in 1859; and from that time onward the facts that (1) man was contemporaneous with the Mammoth, and (2) that he manufactured flint implements, have become more and more generally accepted, until, at the present time, it would be difficult to find anyone who, having paid attention to the subject, doubts either of these two propositions.

It being well established that man existed in later Pleistocene times, that is to say, after the great Glacial period, we are naturally interested to know whether this was his earliest appearance, or whether his advent was before that time of extreme cold; in other words, did man exist on the earth in what we know as the Tertiary period?

* *Brit. Assoc. Rep.*, 1896.

† *Antiquités Celtiques*, vol. i, 1847.

MAY, 1897.]

Much evidence has been brought forward which, if correct would prove that man *was* present, not only in the Pliocene, or latest Tertiary period, but also in the somewhat earlier times of the Miocene.

This evidence, however, is not so satisfactory as could be wished; and notwithstanding that it is accepted by several continental anthropologists as proving the existence of man in the Tertiary period, yet it has been severely criticised in this country, and is not accepted by our masters of the science. Sir John Evans has on several occasions said that the evidence for Tertiary man is incomplete.* Prof. W. Boyd Dawkins† and Prof. T. McKenny Hughes‡ have expressed the same opinion, which was, I believe, held also by the late Sir Joseph Prestwich unless indeed we must except the Kentish plateau implements which he thought might be of Pliocene age.§

Within the last few years several important additions have been made to our knowledge respecting the antiquity of man, and it seems to me that the time has come when it will be profitable, as well as interesting, to review the information which has been presented to us as "Evidence of the Tertiary Age of Man." This evidence consists in the reputed discovery of human bones, or of objects showing human handiwork, in strata of Tertiary age.

The difficulties which beset this inquiry will be appreciated by all who, with unprejudiced minds, have endeavoured to weigh the evidence; and the necessary facts are so frequently wanting, that there is often a tendency for us to become satisfied with incomplete evidence. It will, therefore, be well for us, at the outset, to remember the three points to which Sir John Evans has called attention, on which the evidence must be quite clear before it can be accepted as definite proof.

1. The remains must be undoubtedly human, or definitely the result of human handiwork.

2. The evidence must be conclusive as to the remains being contemporaneous with the beds in which they were found.

3. The age of the bed itself must be certain.

Another difficulty meets us at the present time, which is that we have to judge without seeing the specimens or the places where they were found. ||

* Evans, *Trans. Hert. Nat. Hist. Soc.*, 1875, p. 187, and *Ibid.*, 1880, p. 145. Addresses, *Geol. Soc.*, Feb., 1875, and *Brit. Assoc. Rep.*, Anthropology, 1890.

† *Brit. Assoc. Rep.*, Anthropol., 1882.

‡ Victoria Institute lecture.

§ A paper on "Tertiary Man" was read before this Association by Mr. J. B. M. Findlay, in March, 1894.

|| This address was illustrated by numerous slides shown in the lantern by the oxy-hydrogen light. Some of these illustrations Dr. Garson was good enough to lend; and two views of the spot where the Burma flints were found, were admirably reproduced at very short notice by Mr. W. W. Watts, from photographs taken by Dr. Noetling and kindly lent by Prof. T. Rupert Jones; Mr. H. Stopes, also, was kind enough to give a photograph of the carved Crag shell. To all these gentlemen and to other friends who rendered valued help the President desires to return his warmest thanks.

In the year 1867 the Abbé Bourgeois made known* his discovery of chipped and burnt flints, which he believed to be of human origin, in beds of Lower Miocene age at Thenay, near Tours, in France; and in 1872 he again brought the matter before the Congress at Brussels.† The Abbé was quite satisfied, not only that the flints showed the handiwork of man, but also that they were really from Miocene beds; he was not able, however, to convince all who saw the specimens that such was the case.

After the Abbé's paper was read fourteen members of the Congress examined the flints then exhibited; of these gentlemen, nine expressed the opinion that some of the flints showed human work, while five were unable to see any traces of such work. According to M. Gabriel de Mortillet, however, it was those gentlemen who were expert in flints who accepted them as showing human work. Judging from the published figures of these flints, some certainly appear to be the result of man's handiwork, and the crackled surface of others looks much as if they had been subjected to the action of fire. M. Mortillet,‡ whose experience in these matters carries no little weight, was satisfied both as to the human work and also that the crackled appearance was due to fire. Under these circumstances one can scarcely doubt that some of the flints had been manipulated by man.

With regard to the age of the beds, in which these flints were said to have been found, there seems to be no question, it being generally admitted that they are of Miocene age. The section of the strata at Thenay given by the Abbé includes nine different beds, the uppermost one, Bed 9, being Alluvium (or Quaternary), while all those below are regarded as Miocene; the greater number of the chipped flints being from Bed 3, which is below the stratum in which *Acerotherium* occurs.

As much doubt had been expressed as to these flints having been found *in situ*—seeing that they were from a railway cutting and a river bank, and might have been derived from the surface, where similar flints were known to occur—the Abbé had a special pit sunk,§ where flints, said to be both worked and burnt, were found at a depth of about 13 feet from the surface, and under conditions which precluded the idea of their coming from the surface. The validity of this proof was maintained by Mortillet in 1885.|| Here, then, we have what seems to be definite evidence as to the worked flints being of Miocene age; but Prof. Haynes, of the United States, who visited Thenay in 1877 and studied the specimens under the guidance of the Abbé Bourgeois, says “none of the flints from the Tertiary beds of Thenay are

* *Congrès International d'Anthropologie*, Paris, 1867, p. 67.

† *Cong. Intern. Anthrop.*, 1872, p. 81.

‡ *Le Préhistorique Antiquité de l'Homme*, 1883, p. 85.

§ *Bull. Soc. Géol. France*, 1869, p. 901.

|| *Le Préhistorique Antig. Homme*, p. 94.

true flakes, although such flakes do occur there upon the surface of the ground."

When those who have seen the original specimens and the place where they were found hold such different opinions regarding them, it is scarcely possible for us to come to any definite conclusion, for even if we accept some of the flints as showing human work, there remains the possibility of these particular ones having been derived from superficial deposits. Unfortunately we have no figures of the specimens which were found in the pits dug by the Abbé Bourgeois. There is still another point: the flints which seem most likely to have been worked are suspiciously like Neolithic forms.

Under these circumstances, however probable it may seem to some of us that these worked flints are of Tertiary age, we can hardly do otherwise than follow Sir John Evans, and say "*Not proven.*"*

As far back as the year 1860 M. Ribeiro discovered worked flints in the Tagus Valley, which were said to have come from beds of Pliocene, or perhaps Miocene, age; but it was in 1872† that he gave an account of his discoveries, which were not well received. The Abbé Bourgeois did not think that any of the flints showed human work, although Sir A. W. Franks was inclined to accept some of them.

In 1878 a number of these flakes were exhibited in the Anthropological section of the Paris Exhibition, and were examined by M. Mortillet, who pronounced twenty-two of them to be the work of man, and believed them to be of Tertiary age. Much doubt, however, was felt as to the amount of reliance that could be placed in the discovery.

In 1880 the Congress of Anthropologists met at Lisbon, and the locality of Otta, where the flints had been found, was visited by several of the members, when one flake was found *in situ*, but unfortunately it was by no means clear that this showed signs of work. A committee had been appointed to investigate these discoveries, which included the names of Cappellini, Cotteau, Evans, Mortillet, Virchow, Villanova, and others. A lively discussion took place,‡ but the result was not decisive; the majority accepted many of the flints as showing intelligent work, but it was not proved satisfactorily that these came from Tertiary beds; so many of the flakes seem to have been found on the surface.

It was during the discussion upon the report of the committee that Prof. Cappellini spoke strongly in favour of this evidence for Tertiary Man, and alluded to Sir John Evans as "the little St. Thomas." M. Villanova, referring to this remark of Prof. Cappellini, said "not only is there a little St. Thomas

* *Brit. Assoc. Rep., Anthropol., 1890.*

† *Cong. Intern. Anthropol., Brussels, p. 95.*

‡ See *Report* for 1880, pub. 1882.

present," but he could assure them "the great St. Thomas" was there also, for he himself doubted the existence of Tertiary Man *in toto*.

As in the 'Thenay discoveries so in those in the Tagus Valley, there are grave elements of doubt; and although there was a general feeling at the Lisbon meeting that this might eventually prove to be a genuine instance of Tertiary Man, yet it was pretty clear that the case had not been definitely proved.

In 1869 M. Tardy * found a worked flint in a conglomerate under a lava flow, which is stated by M. B. Rames to be of Upper Miocene age, at Puy Courny, near Aurillac, Auvergne. There seems to be no doubt as to this being a genuine worked flint, for it is accepted by M. de Mortillet † and by Sir John Evans, ‡ but unfortunately the specimen seems to have been found near the surface of the ground and in a position where it may easily have been derived from Quaternary deposits; moreover the flint resembles flakes which are not uncommon in those more recent beds.

Some years later (1877) M. B. Rames obtained a number of small flints from the same locality, and apparently from lower down in the beds which contain *Mastodon*, *Dinotherium*, and *Hipparion*; and subsequently § gave an account of the geology of the neighbourhood of Puy Courny. M. Mortillet accepts these flints as showing intelligent work, || and they are said to resemble pointed flakes of acknowledged artificial origin, a statement which the figure seems fully to justify. Here, however, we are met with the usual difficulty: was this specimen and those accepted by M. de Mortillet actually found *in situ*? and upon this point there is some uncertainty. Evidently the Puy Courny flakes found *in situ* are not such as to convey conviction to all minds, for M. Marcelin Boule ¶ looks upon them as merely resulting from the erosion of an ancient river; Prof. Haynes does not accept them, ** nor, apparently, does Sir John Evans.

The occurrence of chipped flints in Pliocene beds at Yenang-young Oilfields, in Burma, was made known in 1894 by Dr. Fritz Noetling. †† In a ferruginous conglomerate, containing remains of *Rhinoceros perimensis*, and *Hipparion antilopinum*, which is overlaid by 4,620 feet of Pliocene strata, Dr. Noetling came upon some chipped flints, partly imbedded in, and projecting from, the conglomerate. The largest and most important of these flakes is about $1\frac{1}{2}$ inches in length, and, judging from the figures, certainly appears to be the result of human workmanship, although it may

* *Bull. Soc. Anthropol.*, 1869, p. 703.

† *Prehist. Antiq. Homme*, 1883, p. 97.

‡ *Trans. Hert. Nat. His. Soc.*, vol. i, 1880, p. 149.

§ *Matériaux*, vol. xviii, p. 400, 1884.

|| *Prehist. Antiq. Homme*, 1883, p. 96.

¶ *Revue Anthropol.*, ser. iii, vol. iv, p. 217.

** Wright, *Man and the Glacial Period*, Appendix, p. 317.

†† *Records Geol. Surv. India*, vol. xxvii, part 3, p. 101, 1894.

be doubted whether the smaller ones are anything more than natural fractures.

With regard to the age of the beds from which these flints are said to have been derived, we cannot go beyond the opinion expressed by Dr. Blanford,* and accepted by Dr. Noetling, that they are most probably of Pliocene age.

Dr. Noetling specially considers the probability of the flints having been found (*in situ*), and says: "To the best of my knowledge they were found *in situ*. The exact spot . . . is on the steep, eastern slope of a ravine, high above its bottom; but below the edge, in such a position that it is inconceivable how the flints should have been brought there by any foreign agency."

This discovery seems to me strong evidence for the presence of man in late Tertiary times, and Prof. Rupert Jones† in his notice of this discovery accepts the evidence.

There is, however, another side to this question which must not be left out of sight. Mr. R. D. Oldham, of the Geological Survey of India,‡ having visited the locality with Dr. Noetling, says that the flints were found on the surface in a thin coating of ferruginous gravel; and although ordinarily there would be no hesitation in ascribing anything found in this layer of loose material to the underlying rock, it is different with worked flints, which if chipped by man may have been dropped on this surface, or washed down from the plateau above, and subsequently have become partly embedded in the weathered surface.

Prof. Grenville Cole,§ raises a protest against Mr. Oldham's extreme scepticism; seeing that, as he thinks, the probabilities are in favour of man's existence in the Pliocene period.

Prof. Rupert Jones has kindly lent me some photographs of the spot where the flints were found, and letters recently received by him from Dr. Noetling, in which the latter speaks more positively both as to the flints being worked by man and as to their really belonging to the bed in which they were partially embedded.||

However, it must be remembered that Mr. R. Oldham was not satisfied that the flints actually belonged to the bed; and it is just possible, as he has suggested, that they have been brought down from the plateau above, or dropped there by man himself at a comparatively recent period, and partially cemented into the ferruginous material in which they were found.

Under these circumstances, it seems to me, one cannot unhesitatingly accept this discovery as a proof of the Tertiary age of man in Burma, however much it may increase the *probability* of man's existence in those early times.

There is still another discovery of chipped flints, for which a

* *Nature*, vol. li, p. 608.

† *Nat. Science*, Nov. 1894, p. 345.

‡ *Nat. Sci.*, Sept. 1895, p. 201.

§ *Nat. Sci.*, Oct. 1895, p. 294.

|| See *Natural Science*, vol. x, 1897, p. 233.

Tertiary age has been claimed, to which attention must be directed. The flints with very rude chipping, found by Mr. Benjamin Harrison, of Ightham, on the high plateau of Kent, have been the cause of much discussion, and within the last few years have been specially brought before our notice by the writings of the late Sir Joseph Prestwich.* Other papers on the same subject have appeared by Mr. Lewis Abbott,† by Prof. Rupert Jones,‡ and by Mr. B. Harrison.§

The greater number of the plateau chipped-flints have been found upon the surface of the ground, and many of the lighter coloured ones are so similar to implements of an acknowledged palæolithic type, and the intentional chipping is so evident, that they can be accepted at once as showing human workmanship; but as they were found upon the surface of the ground it is quite possible they may be of Palæolithic age. But with these accepted implements are others of a dark brown colour, showing chipping of such a rude character that many persons are unable to see in them any evidence of human work.

Now, these brown flints, it is said, are derived from the Plateau gravel, which Sir Joseph Prestwich refers to a much earlier date than the beds which have hitherto yielded palæolithic implements. If, then, these brown, rudely-chipped flints are of the same age as the Plateau gravel, and are truly worked, we have in them evidence of a race of men more ancient than Palæolithic Man, and, according to some, possibly of Pliocene age. The interest attaching to these brown flints is, therefore, great; and for this very reason all the circumstances relating to the discovery must be critically examined.

In the first place. Do these brown flints really show human work? It must be admitted that, even to the eye of an experienced judge of flint implements, many of them are far from possessing that undoubted evidence of design which would by itself carry conviction of their being human workmanship. Not only is the chipping very primitive, but the chipped edges are in many cases almost worn away.

When I first had the opportunity of examining some of these rudely-chipped flints I was quite unable to see any evidence of human work upon them, and it was not until the GEOLOGISTS' ASSOCIATION visited Mr. Harrison, and he had spread out before us a very large number of specimens, that I began to appreciate how the forms which at first seemed meaningless were intentionally formed. A single specimen such as that figured by Sir J. Prestwich,|| especially if somewhat worn, did not at first convey

* *Quart. Journ. Geol. Soc.*, vol. xlv, p. 270, 1889; *ibid.*, vol. xlvii, p. 126, 1891; *Journ. Anthr. Inst.*, vol. xxi, 1892; and in *Controverted Questions of Geology*, 1895.

† *Natural Science*, vol. iv, p. 257, 1894.

‡ *Brit. Assoc. Rep.*, 1894, and *Natural Science*, vol. v, p. 269, 1894.

§ *Brit. Assoc. Rep.*, Ipswich, p. 349, 1895.

|| *Controverted Questions in Geology*, plate 12, fig. 41.

the idea of human intent, but when an extensive series was laid before us, all of the same type, one could not resist the feeling that they had been intentionally made of this hollow form ; and a close examination of the chipping confirmed this impression. And again, when this series was continued by others more and more worn, one was led to the conviction that many other flints which at first seemed shapeless were really denuded examples of the same type.

Most of the forms figured by Sir Joseph Prestwich are illustrated by numerous specimens in the possession of Mr. Harrison.

At the present time, I believe that the majority of those persons who have carefully examined these brown, chipped flints, acknowledge that some at least of them show evidence of human work ; and I think I am right in saying Sir John Evans accepts some of them. Mr. F. C. J. Spurrell, Mr. W. Cunnington, and Mr. Worthington Smith appear to be unable to accept any of them as the work of man.

We now come to the second point. Did these brown, chipped flints really come from the Plateau gravel ?

All the earlier specimens were picked up on the surface of the fields, and might have been brought there at any time subsequent to the deposition of the underlying gravels ; and it was not until 1895 that they were met with at any depth below the surface. Some few, it is true, had been got from shallow pits which had now and again been dug in the surface soil ; but these could not be accepted as good evidence. In order, therefore, to settle this question the British Association made a grant to defray the expenses of a special excavation, and this was carried out under the direction of Mr. B. Harrison, at Parsonage Farm, Stanstead.

Several pits have now been dug at this spot, and in each of them, under about $2\frac{1}{2}$ feet of humus and $3\frac{1}{2}$ feet of grey loam, a bed of gravel was met with, which yielded a number of dark-brown, chipped flints like those previously collected on the surface. There is no longer any doubt that brown, chipped flints occur at a depth of 7 feet or 8 feet at Stanstead Parsonage Farm ; and the chipping of many of these flints is believed to be the result of human work. One pit was excavated to a depth of 26 feet, but below 8 feet only Tertiary sands and pebbles were met with.

At this point we meet with a difficulty. Is the gravel met with at a depth of 8 feet, at Stanstead Parsonage Farm, really undisturbed Plateau gravel ? And this, I think, requires further investigation, for the clay-with-flints, exposed to a depth of about 10 feet somewhat higher up the slope, is of a very different character ; no brown, chipped flints seem to have been found in it, but it contains many large, unworn, unbroken, and light-coloured flints.

In the third place. What is the age of these Plateau gravels ?

Sir Joseph Prestwich studied this question very carefully,* and the section he gives from the Thames, near Northfleet, southward to Oldbury Hill, shows that at about half-a-mile south of the Thames the Chalk forms an escarpment of from 80 to 100 feet above O.D., and is here capped by gravel rich in palæolithic implements, and yielding also extinct mammalia. Further south, at Swanscomb Hill, the Chalk is overlaid by Tertiary beds, and at an elevation of 320 feet gravel occurs. From the surface of this gravel Mr. Spurrell obtained a palæolithic implement. Still further southward the Chalk is not covered by Tertiary beds, and rises gradually to the neighbourhood of West Yoke, where, at a height of 460 feet, it is covered by the Plateau gravel, which continues as far south as Terry's Lodge, where the Chalk attains a height of 700 feet, and forms the southern escarpment of the North Downs. Still passing southwards, the Upper Greensand, Gault, and Lower Greensand are met with cropping out from beneath the Chalk; the Gault forming a valley, and the Lower Greensand rising on the south to a height of 600 feet at Oldbury Hill.

It is in or upon this Plateau gravel that the rudely-chipped dark-brown flints occur, at elevations of between 400 and 700 feet. With these implements unworked flints of a dark colour are likewise found, and with them occasionally pieces of chert, Oldbury-stone, and ragstone.

Sir Joseph Prestwich contends that this Plateau gravel is older than the High terrace-gravel of Milton Street (100 ft. O.D.) and other localities of similar elevation; first, because of its greater elevation, and secondly, because it contains fragments of rock which could only have been derived from the Lower Greensand hills to the south, and that at a time when the valley which now intervenes was not excavated. In other words, since the pieces of chert and ragstone were able to pass over from the Lower Greensand on to the Chalk plateau, sufficient time must have elapsed to allow of the denudation of the now intervening valley, and this must indicate a very prolonged period; and was, according to Sir Joseph Prestwich, long before the deposition of the terrace gravels (at 100 ft.), in which the ordinary palæolithic implements have been met with.

The same authority has maintained that these Plateau gravels must have been deposited after the earlier Pliocene period as represented by the Lenham beds, and before the excavation of the valleys of this district, which he believed was accomplished in Glacial times.

Although this theory of the origin and age of the Plateau gravels is accepted by many geologists, some regarding them as of Pliocene age, there are others, among those most competent to judge, who think these gravels may have had a more recent origin, and may be of late Pleistocene date.

* *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 126, 1891.

Moreover, this gravel varies at different places, and it may well be that this is indicative of diversity of origin. As I have already mentioned, the gravel at Parsonage Farm, in which the brown flints were found, differs from the red clay-with-flints met with higher up the slope.

The results of this inquiry regarding the Plateau chipped flints may be summed up thus :

1. Some of the rudely-chipped, brown flints have been worked by man.

2. Brown flints worked by man occur at a depth of 7 to 8 feet at Parsonage Farm, Stanstead ; but it is not quite certain that this deposit is undisturbed Plateau gravel.

3. The Pliocene age of these Plateau gravels is by no means certainly established, and consequently worked flints which may be found in them cannot be accepted as definite proof of Tertiary Man.

Mr. Lewis Abbott has given us, in the February number of *Natural Science*, an account of some chipped flints which he has discovered in the "Forest Bed" of Cromer, a deposit which is regarded as the latest of our Tertiary strata. Some of these flints were found in the bed itself and others on the beach near by ; but they all show a peculiar chipping which Mr. Abbott believes to be the handiwork of man. I have had the opportunity of seeing some of these specimens, but I cannot feel satisfied that they show artificial chipping. Some experts are said to accept these flints as showing genuine human work, but Sir John Evans speaks very doubtfully about them. It is too early to speak positively about this discovery, which may ultimately prove to be correct ; but I do not think we are yet in a position to say that it is a proof of the existence of Tertiary Man.

We have now to turn our attention to evidence of a somewhat different kind, that is to say, to the bones, teeth, and other fossils, which are supposed to have been incised or otherwise manipulated by Man in Tertiary times.

The Abbé Bourgeois in 1867 * called attention to a discovery which had just been made by the Abbé Delaunay. It appears that bones of *Halitherium* had been found, in beds of Miocene age, near Pouancé, Maine et Loire, showing deep incisions, and these it was thought had been made by man in hacking off the flesh.

Scratched bones and flints, supposed to be the work of man, were described by M. Desnoyers † from the Pliocene beds of Saint Prest, near Chartres ; they were again noticed in 1867 ‡ by the Abbé Bourgeois, who, however, could not accept either the scratched bones or the flints as showing anything but natural and accidental markings.

* *Cong. Intern. Anthropol.*, Paris, 1867, p. 74.

† *Comptes rendus*, 1863, p. 1077.

‡ *Ibid.*, 1867, p. 47.

In 1871 M. Farge* presented to the Geological Society of France a humerus of *Halitherium* from the Faluns of Chavagnelles-Eaux, Maine et Loire, having incisions like those in the bones from Pouancé, but not so deep; and these incisions he, following M. Delfortrie, attributed to the teeth of the large sharks which existed at the same time.

In 1875 Prof. Cappellini of Bologna† found at Poggiarone, near Monte Aperto, in the province of Sienna, the bones of a Cetacean which were marked by deep incisions, and these he thought had been made by man. These bones were from beds of about the same age as the Antwerp Crag. Prof. Cappellini says of these bones: "The form of the incisions and the place where they were found, witness in an undeniable manner to the action of some being using an instrument or tool; many naturalists and anatomists who have seen the specimens agree with this." The bones seem only to have been cut on one side, and this is accounted for by the supposition that the animal was stranded in shallow water, and that the flesh was cut off by implements of flint or other material.

The question of these incised bones was brought before the Anthropological Congress at Budapest in 1876,‡ when Sir John Evans said, there was no doubt as to the incisions being ancient; but he thought they were most probably made by some carnivorous fish; an idea which had already been suggested; a similar opinion was expressed by others present at the Congress. Subsequently M. Magitot tried the experiment of attacking the bones of a cetacean with the rostrum of a sword-fish [? saw-fish], and, in his opinion, similar deep cuts were produced. Prof. Cappellini, however, thought the incisions thus made differed from those found upon the fossil bones.

Prof. W. Boyd Dawkins having examined some of the incised bones in the museum at Florence,§ thought that one of them had been partly cut through and then broken; but in spite of the mineralised condition of this specimen he doubted its being of Pliocene age.

The result of this controversy seems to be that most of those who have examined the bones believe the incisions upon them to have been made by some marine animal, and probably by the monster shark, *Carcharodon megalodon*, the teeth of which are found in the same beds.

Some broken bones, found by MM. Garrigou and Filhol fils, in 1864,|| in Miocene beds at Sansan, were supposed to have been cracked by man in order to extract the marrow, but they were not accepted as such. And when these specimens were

* *Bull. Soc. Géol. Fr.*, ser. ii, vol. xxviii, p. 265.

† *Bull. Inst. Bolog.*, 1875, *Atti R. Accad. dei Lincei*, ser. 2, vol. iii, 1876.

‡ Vol. i, p. 46.

§ *Early Man in Britain*, p. 91.

|| *Comptes rendus*, 1864, p. 819.

again brought forward in 1871,* a similar opinion was expressed by those competent to judge.

M. von Ducher† obtained from the Upper Miocene of Pikermi, bones which he thought had been broken by man; but these again appear to have been accidental fractures, and have not been accepted.

Prof. Gastaldi in 1876‡ gave an account of a Mastodon's scapula from the Pliocene of Piémont, which showed a large hole evidently made during life, a deposit of bone around the hole showing that it was partly healed. This hole was supposed to have been made by a Tertiary man; but it is much more likely to have been made by the tusk of another Mastodon, an explanation now generally believed to be the correct one.

Our old friend, the late Edward Charlesworth, brought before the Anthropological Institute in 1872,§ some sharks' teeth from the Suffolk Crag, which were pierced each by a nicely rounded hole in the middle of the base; this hole he believed to have been drilled by man, and he compared these with the smaller sharks' teeth, similarly drilled at the base, and used by some of the South Sea Islanders at the present day, to make very formidable weapons.

I have been unable to trace the resting-place of the Crag bored-teeth, or any published figures, but Mr. F. W. Rudler possesses a water colour drawing of one of them made under the direction of Mr. Charlesworth, and this seems to be a tooth of *Oxyrhina xiphodon*.

Mr. Charlesworth was well acquainted with the borings of molluscs, which are so common in Red Crag bones, but these he thought were not of the same character as those in the teeth he exhibited.

Prof. T. McKenny Hughes,|| however, was convinced that these apertures were made by *Lithodomus*, or some such boring mollusc, and could not admit the likelihood of their being due to man. Prof. G. Busk held the same opinion, which is undoubtedly the correct one.

In the year 1873,¶ Mr. Frank Calvert noticed some flint flakes, broken bones and drawings on bones which were said to have been obtained from beds of Miocene age on the shores of the Dardanelles. This led to a hot discussion, it is said, between Schlieman and Calvert; but the specimens seem never to have been produced by Mr. Calvert in proof of his statements.

Mr. H. Stopes, of Swanscomb, whose collection of flint implements is known to most of our members, brought before the British Association in 1881** a Red Crag shell found

* *Cong. Intern. Anthropol.*, Bologna, 1871, p. 130.

† *Cong. Intern. Anthropol.*, Brussels, 1872, p. 104.

‡ Frammenti di Paleontologia italiana, *Atti R. Acc. Lincei*, ser. 2, vol. iii, p. 497, 1876.

§ *Journ. Anthropol. Inst.*, vol. ii, p. 91, 1873.

|| *Geol. Mag.*, vol. ix, 1872, p. 247.

¶ *Journ. Anthropol. Inst.*, vol. iii, p. 127.

** *Brit. Assoc. Rep.* 1881, York, p. 700.

at Walton-on-the-Naze, on which was cut a rude representation of a human face. This shell is still in the possession of Mr. Stopes, who has kindly supplied me with a photograph of it for exhibition.

Mr. Stopes is fully aware of the doubts which exist as to this being really a prehistoric piece of human work, and is willing to have it tested in every possible way. In his published account he says: "This shell was found in the Crag, properly stratified (and not in the talus), by a gentleman having good knowledge of geology, who would not be unable to judge or know the value of marking well all the surroundings and exact position of the shell. Owing to a dislike of the effects of the discovery, he did not publish it at the time, and a little while ago gave the shell to me." The gentleman who found the shell is not now living.

There is no doubt as to the engraving upon the shell being human work; there is no reason for questioning the shell having come from the Crag at Walton; and there is no doubt as to these beds being of Pliocene age. The one element of doubt in this case is whether the shell was thus incised when it was first exhumed from the undisturbed Crag. The evidence of the finder, as stated by Mr. Stopes, is clear enough; but the general feeling is that he was mistaken as to the shell being *in situ* in undisturbed Crag. However, it must be admitted that the finder was himself satisfied as to the shell being *in situ* when he came upon it.

There is another point to be noticed: the dark red shells from the Crag, like this one, when scratched and cut, are found to be white below the surface. Now, the incisions upon this shell are as nearly as possible the same colour as the general surface of the shell. Of course, the newly-cut surface might be painted; but my experience is that these shells do not readily take water-colour, which comes off much more easily than it is put on.

Within the last week or two I have again examined this shell, and have tried to wash off the colour of the engraved parts with warm water and with alcohol; but without success. The colour of the engraved portions is as firm as that of the rest of the shell.

It is possible that, if this shell had been lying in the ferruginous Crag talus for some months after it was carved, the carving might have become stained; but I have no evidence on this point.

Mr. Dalton, formerly of the Geological Survey, who has had the opportunity of examining the specimen very carefully, is satisfied that it is genuine; and he thinks that the sand grains which are in the scratches could not have been pressed into the hollows as they are, except by pressure such as would obtain in the Crag; but with this I can scarcely agree.

There is still another side to this question. If this shell was

engraved at the time the Walton Crag was being deposited it was doubtless a *recent* shell when carved, and consequently must have been much harder and more difficult to engrave, for *Pectunculus* is exceedingly hard and porcellanous ; and more than this, the tool marks would not be the same, and therefore presumably would not so nearly resemble the tool marks I made on a Crag shell. It seems to me, therefore, much more probable that this shell was carved after it had become a Crag fossil than before.

In a letter lately received I am told that it was reported in a local newspaper (probably Ipswich) that a carved Crag shell, exhibited in the Ipswich (?) Museum, had been carved by an excursionist for amusement and afterwards thrown away. I have not been able to find this newspaper report so as to verify this statement ; and further than this, it is not clear that this report referred to Mr. Stopes' specimen.

I am afraid there is too much doubt hanging over this carved Crag shell to allow us to accept it as definite evidence of Tertiary Man.

We have now to consider the human bones supposed to be of Tertiary age, which have from time to time been made known.

In the year 1867 Prof. Arthur Issel* gave an account of the discovery which had been made about ten years before of a human skeleton in Pliocene beds at Colle del Vento, near Savona, Gulf of Genoa. These bones were said to be almost in their natural relations and embedded, at a depth of three metres, in a compact clay containing great numbers of the fossil oysters which are common in the Pliocene beds of that district. No section of the strata was published and only a fragment of a jaw was figured.

Prof. Issel believed the skeleton to be of the same age as the bed in which it was found ; but unfortunately the exact conditions under which the bones occurred seem not to have been carefully examined at the time of their discovery ; and it is now generally believed that the remains were due to a comparatively modern interment.

At Castenedolo, near Brescia in Lombardy, in the year 1860, Prof. Ragazzoni found in Pliocene beds a cranium and other human bones ; but at that time they were neglected, the impression being that the remains were quite modern. Subsequently four other skeletons were unearthed.† The finding of several human skeletons in a marine Pliocene formation, and near together, was to say the least remarkable, and was accounted for by one writer by the supposition that this was the result of the shipwreck of a family party in the Pliocene sea. In the absence of very definite evidence as to the condition of the overlying earth it is more reasonable to suppose that these bodies had been interred at a much later date, and this is the view now generally

* *Cong. Intern. Anthropol.*, 1867, p. 75.

† See *Sentinella Bresciana*, April, 1880 [I have not seen this paper] ; and Issel, *Bull. Paleont. Italiana*, vol. xv, p. 89, 1889.

accepted. M. Topinard,* who had seen the skeletons and the place where they were found, did not believe them to be contemporaneous with the Pliocene beds.

Prof. Cocchi, in the year 1867,† made known the discovery of a human skull and flint implement in a railway cutting at Olmo, near Arezzo, Italy, which he believed to be from beds of Quaternary age; but Dr. Forsyth Major‡ seemed to think the remains were of Pliocene date; M. de Mortillet§ refers the skull to the Quaternary, while Prof. Boyd Dawkins|| and Sir J. Evans¶ look upon both the skull and flint as Neolithic. It appears that the remains were found after a slip in the sides of the cutting, and although supposed to have come from Pliocene beds, fifteen metres from the surface, it is by no means clear from what part of the section they really came.

In the year 1855 a human jaw was found by the workers employed in excavating Coprolites at Foxhall in Suffolk, and was purchased by Mr. John Taylor, a chemist at Ipswich. In 1863 it was exhibited at the Ethnological Society, and in 1867 Dr. Robert Collyer gave an account of the specimen in *The Anthropological Review*,** and a very amusing account, too.

This jaw was infiltrated with oxide of iron, and was supposed to have come from the Coprolite layer at the base of the Red Crag, but there was no absolute proof of this. The jaw was examined by Lyell, Murchison, Prestwich, Owen, Busk, Falconer, Huxley, and others, but none of them could accept it as a "Coprolite bed" fossil; neither could they see any characters indicative of such a great antiquity. The claims put forward for the Pliocene age of this relic could not be established.

The famous "Calaveras skull" found in the Californian auriferous gravels must now be noticed. It appears that since the year 1850 numerous objects of human manufacture, in addition to the famous skull, have been found from time to time in these auriferous deposits; and from these same beds, at different localities, have also been obtained bones and teeth of Mastodon, Elephant, and Horse. The presence of Mastodon and the enormous amount of denudation which has taken place since the deposition of the beds have led to their being regarded as of Pliocene age. The objects of human workmanship which have been found in these same deposits are large stone mortars, with stone pestles, as well as obsidian spear and arrow heads, a full account of which was given by Prof. Whitney when describing the "Calaveras skull."††

* *Rev. Anthropol.*, ser. 3, vol. i, pp. 563, and 742, 1886.

† *Mem. del. Soc. Ital. Sci. Nat. Milano*, vol. iii, No. 7, 1867.

‡ *Soc. Ital. di Anthropol. e. di Etnol.*, April, 1876.

§ *Le Préhistorique Antiq. Homme*, p. 350.

|| *Early Man in Britain*, p. 91.

¶ *Brit. Assoc. Rep.*, 1890; *Nature*, Sept., 1890, p. 507.

** Vol. v, p. 221.

†† *Memoirs Harvard Museum of Comparative Zoology*, vol. vi, p. 258, 1880.

The Calaveras skull was found in 1866, and is said to have come from the auriferous gravel, about 120 feet below the lava flow, at Bald Mountain. There is no doubt about this being a human skull, and there is nothing in its form to indicate any great antiquity; indeed, it is acknowledged to be like the skulls of American Indians now or recently living in the district. In the year 1889 Mr. M. A. Kurtz,* in boring an artesian well at Nampa, Ada County, Idaho, brought up in the sand pump from a depth of 320 feet, under a similar lava to that of Table Mountain, a miniature clay image.

In 1891 Mr. George Becker† gave an account of a very perfect stone pestle and mortar discovered by Mr. J. H. Neale, when driving the Montezuma Tunnel under Table Mountain. Another stone pestle was taken out by Mr. Clarence King; and a stone mortar from the auriferous gravels of Grass Valley, California, obtained by Mr. S. B. J. Skertchley, is exhibited in the Museum of Practical Geology.

The geological structure of the Table Mountains is peculiar, and their general features being similar, the description of Bald Mountain, where the skull was found, will be sufficient for our present purpose. According to Prof. Whitney, the top bed is the black lava flow, which may be 40 feet thick, and its upper surface is some 2,000 feet above the valley; below the lava are found stratified deposits of alternating gravels and light lavas of varying thickness, but having a total depth of over 100 feet, and evidently occupying an old river bed, cut in the underlying strata, which consists of much altered rocks, probably of Secondary age. It was from one of the beds of gravel, about 20 feet from the bottom of the river bed, that the skull was said to have been obtained. It is tolerably evident that a river once flowed along this old channel and deposited the gravel; also that at distant intervals lava flowed down and covered the gravels, this being repeated until at length the channel was filled and the river diverted from its course. The denudation of the land, not covered by lava, continued, while the old river gravels were protected by their covering of basalt.

At the present time the rivers which flow on either side have cut down their valleys to nearly 2,000 feet below the old river bed, which, with its covering of basalt, now forms the top of Bald Mountain. It will be obvious, that since the lower auriferous gravels were deposited, sufficient time must have elapsed for all these events to have taken place, including the cutting down of the valleys to 2,000 feet.

Prof. Whitney bearing these facts in mind, and knowing that similar gravels near by had yielded Mastodon and Elephant remains, regarded these auriferous gravels as of Pliocene age,

* See Wright, *Man and the Glacial Period*, p. 297, 1892.

† *Bull. Geol. Soc. Am.*, vol. ii, p. 189, 1891.

and consequently thought that the "Calaveras skull" was a Tertiary representative of Man.

In putting these Californian discoveries to the usual tests we shall have no trouble as to the skull being human, nor as to the objects found being of human workmanship. The skull, as we have said, may well have been that of a comparatively modern American Indian, while the mortars and other objects are likewise of a very recent type; and these facts must be allowed their due weight when a Tertiary age is claimed for the remains.

But now comes the question—Did the skull really come from the undisturbed auriferous gravel?

Prof. Whitney has shown strong reasons for thinking that it did. Mr. Mattison, the owner of the workings, is said to have got it out himself, but the evidence does not seem very clear on this point, and the discovery has, by many people, been regarded as a hoax. With regard to the earlier discoveries of mortars and implements there is likewise much doubt as to their having been found *in situ*, but the instances cited by Mr. Becker, and accepted by Dr. G. F. Wright, are more satisfactory, and it seems probable that they are truly from the auriferous gravels.

In the last place—Is the age of these auriferous gravels certainly known?

The presence of Mastodon remains we now know is no proof of the Pliocene age of these deposits, for it is generally admitted that the genus continued to live into Pleistocene times in North America. And besides this, the evidence at present adduced leaves it somewhat uncertain whether the mammalian remains found in these beds may not have been derived from some older deposit, and if this be so, then the auriferous gravels may be of still more recent origin, which would accord much better with the objects of human workmanship said to have been found in them, as it would also with the modern character of the human skull itself. Mr. G. F. Becker thinks* that the human remains were contemporaneous with the extinct animals, but that the latter existed to a later period than has been supposed. The large amount of denudation which has taken place since these auriferous gravels were deposited certainly seems to point to a vast lapse of time, but their age is far from being definitely settled, and Dr. G. F. Wright is of opinion† that the glaciation and lava flows of California are much more recent than has been supposed. It seems likely therefore that after all the age of these gravels will prove to be, not Tertiary, but late Pleistocene, if not indeed, as the specimens themselves would lead us to expect, Neolithic. However this may be, we shall all, I think, agree with Professor Haynes,‡ that it will be well to wait for better evidence before we

* *Bull. Geol. Soc. Am.*, vol. ii, p. 189, 1891.

† *Man and the Glacial Period*, p. 299.

‡ Appendix to Wright, *Man and the Glacial Period*, p. 374.

can admit that the existence of Tertiary Man upon the Pacific Coast has been established.

Perhaps the most interesting discovery which has been made for many years in the domain of Anthropology is that which was published in 1894 by Dr. Dubois, when he first described the "Missing Link."* In the course of explorations which he had carried on, in search of mammalian remains, in the neighbourhood of Trinil, a small farm on the Bengawan river in the district of Ngawi, Java, he obtained the remarkable skull, teeth, and femur to which he gave the name of *Pithecanthropus erectus*.

It will be well, in the first place, to notice the geological conditions under which these remains were found. The river Bengawan has cut its way down into a plain formed by a thick deposit of sandstone and andesitic tuffs, and the explorations were made in beds below the dry season level of the river, and some 30 or 40 feet below the level of the plain. The section of the strata, given by Dr. Dubois in his second paper,† shows a considerable thickness (25 to 30 feet) of soft sandstone; under this some 3 feet of "Lapilli rock," in the lower part of which *Pithecanthropus* was discovered; and then a stratum of conglomerate; below these again is "Clay rock," resting upon an eroded surface of Marine breccia.

In all the beds above the "Clay rock" fossil bones have been met with; but they are rare in the conglomerate and in the upper part of the sandstone, but numerous in the "Lapilli rock," in which this remarkable skull was found. The mammalian bones found in these beds belong to such forms as *Elephas*, *Stegodon*, *Bubalus*, *Rhinoceros*, *Hexaprotodon*, *Hyæna*, *Felis*, etc., and represent a fauna, allied to that of the Sewalik Hills, which is of late Pliocene, or it may be of early Pleistocene age.

The parts of *Pithecanthropus* discovered are the calvaria, a femur, and two teeth; these were not found together, but were on exactly the same level, although some distance apart, and there is little doubt that they belonged to the same individual.

In November, 1895, Dr. Dubois exhibited the *Pithecanthropus* remains at a meeting of the Anthropological Institute; and he had already shown them at Leyden, at Dublin, and at Edinburgh. Many anthropologists and anatomists, therefore, have had the opportunity of examining the original specimens—a privilege which it fell to my lot to share. It may be mentioned that these bones are heavy, highly mineralized, and of a dark brown colour, similar to those of the other animals found in the same deposit; so that there is no reason for questioning their being of the same age.

* *Pithecanthropus erectus, eine menschenähnliche Uebergangsform aus Java*, 4°, Batavia, 1894.

† *Anat. Anzeiger*, vol. xii, No. 1, 1896.

The calvaria bears a striking resemblance to that from the Neanderthal, but it is much smaller, the large supraciliary ridges, the narrowness of the region behind the orbits, and the inflated parietals being much alike in the two skulls. The frontals of the Java skull, however, are even more depressed than they are in the Neanderthal calvaria. In size the Java specimen is intermediate between the skull of a human being and that of a gorilla, its internal capacity being calculated to be about 1,000 cubic centimetres—the brain capacity of a gorilla being about 500 to 600 c.c.; that of Europeans averaging 1,400 to 1,500 c.c. The femur believed to belong to *Pithecanthropus* agrees, both in size and form, with that of a man.

There is much diversity of opinion among anatomists as to whether this Java skull is an abnormally small and ape-like human skull, or an extremely large and man-like ape's skull.* Dr. Dubois regards it as an intermediate form, and calls it "the missing link." Prof. Virchow, with others, seems to think *Pithecanthropus* is more nearly allied to the apes than to man. Sir W. Turner is not alone in regarding this Java skull as that of an abnormal human being. Prof. Manouvrier, while agreeing with Dr. Dubois that *Pithecanthropus* is a "missing link," thinks that it is nearer to man than to the apes; indeed, he would place it in the genus *Homo*, but in a distinct species.

If size alone be considered, no doubt the gorilla and chimpanzee are more like man than is any other kind of ape; but in similarity of form it is the much smaller gibbon (*Hylobates*) which makes the nearest approach. Now, it is pretty well agreed that this Java skull has far more resemblance to that of *Hylobates* than it has to any of the larger apes; indeed, so close is the resemblance that the skull and femur of a *Hylobates* of twice the normal size would agree in a most remarkable manner with these Javan remains. Not only would the skull have very nearly the same form, but the brain capacity would be as great, or perhaps somewhat greater, than is the calculated capacity of the Java calvaria.

Dr. Dubois has called attention to the fact that among the mammals found in these Java deposits there are several forms similar to species now living, but of gigantic size; he particularly notices a Hyæna and a Pangolin. With these facts before us it seems quite possible that we have in *Pithecanthropus* a gigantic form of *Hylobates*, and possibly a progenitor of man. And further, when this skull is compared with that from the Neanderthal, and with the one from Santos in Brazil, recently described by Dr. Nehring,† it is difficult to resist the conclusion that Dr. Dubois was right in speaking of *Pithecanthropus* as the veritable "missing link."

* See Dubois, *Anat. Anzeiger*, vol. xii, No. 1, p. 14, 1896.

† *Verhandl. Berlin Anthropol. Gesells.*, p. 710, Nov., 1895.

But now we must ask the question—Can we accept *Pithecanthropus* as a proof of the existence of Tertiary Man?

If, as some think, these Javan remains are human, we are still to some extent uncertain as to their age; there seems a possibility of their being early Pleistocene and not Tertiary. If, on the other hand, the beds prove to be of late Pliocene age, we are not in a position to say positively that the remains are human.

And again, if we regard *Pithecanthropus* as a Simian progenitor of man, “the missing link,” a genuine *Homo insapiens*, with only a budding intellect; then it is hardly likely that a veritable *Homo sapiens*, a really intellectual human being, lived at the same time; he in all probability advanced to the sapient stage at a later period. Of course it is possible that an early insapient type may have persisted in one area, while in another it advanced to the sapient stage, but this presupposes a still earlier time for the first appearance of the insapient form, and for this, at present, we have no certain evidence; and consequently from this point of view the discovery of *Pithecanthropus* might be taken as an item of evidence against the presence of “Man” in the Tertiary period.

I have endeavoured this evening to lay before you, in an impartial manner, the chief evidence that has been brought forward for the presence of Man in the Tertiary Period. There will doubtless be some difference of opinion as to the value to be attached to various portions of this evidence; some, following certain continental anthropologists, may be satisfied that Man existed in Tertiary times, while others will feel, with the majority of our countrymen, that there is at present no satisfactory proof of his presence at that early period.

A definite settlement of the question is much to be desired; but we must be careful not to draw hasty conclusions, which ascertained facts do not really justify. On the whole, I think there is at the present time more fear of unstable evidence being accepted as proof than of positive proof being ignored when such is really forthcoming. Not one of the many records that have been noticed this evening is, to my mind, conclusive as to the existence of Man in the Tertiary Period; but at the same time, it must be admitted, some of the discoveries are so nearly proved that there seems a possibility, not to say a probability, of these ultimately being found to be correct.

There are so many astute workers now on the alert, among whom members of the Geologists' Association hold no mean place, that if Man really existed in Tertiary times we shall assuredly before long obtain the desired evidence; in the meantime we must “Learn to labour and to wait.”

ORDINARY MEETING.

FRIDAY, FEBRUARY 5TH, 1897.

President, E. T. NEWTON, F.R.S., in the Chair.

The minutes of the previous meeting were read and confirmed.

Egbert Thomas Sheaf, Sir James R. G. Maitland, Bart., F.L.S., F.G.S., and the Rev. Henry Dawson, M.A., were elected members of the Association.

There being no further business, the meeting then terminated.

ORDINARY MEETING.

FRIDAY, MARCH 5TH, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected members of the Association: Charles Baron Clarke, M.A., F.R.S.; Henry Ullyett, B.Sc., F.R.G.S.; Wm. Chamberlin Salmon, John Wm. Garnham, David Taylor, Frederic L. Watkins, Sydney Newton Glass.

A lecture was delivered by Prof. H. A. MIERS, F.R.S., on "Some Properties of Precious Stones."

Mr. GWINNELL exhibited a metatarsal of *Dinornis maximus* from Canterbury, New Zealand.

ORDINARY MEETING.

FRIDAY, APRIL 2ND, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected members of the Association: Thos. Wm. Shore, F.G.S., Percival Martin, Ernest Machin.

Mr. TREACHER gave some remarks on a collection of Flint Implements from Cookham.

A paper was read by GEORGE DOWKER, F.G.S., on "The Physical History of Romney Marsh."

MAY, 1897.]

ORDINARY MEETING.

FRIDAY, MAY 7TH, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected members of the Association: Capt. A. W. Hicks Beach, Henry Edmonds, B.Sc., William Creighton, Frederic Bernard Edmonds, and James Francis.

Mr. A. E. SALTER exhibited a neolithic celt from Thornton Heath.

Mr. W. W. WATTS, M.A., F.G.S., delivered a lecture on "Coral Islands," which was illustrated by the lantern and by models in coloured clay. Some of the results of the recent expedition organised by the Royal Society to put a boring through the atoll of Funafuti, in the Pacific, were briefly described, and a diagram shown of the remarkable slope of the outside of the reef. It was announced that Professor Edgeworth David was going out to Funafuti in the hope of penetrating the reef to a greater depth than had been hitherto reached.

VISIT TO THE ROYAL COLLEGE OF SURGEONS.

SATURDAY, MARCH 27TH, 1897.

Director: Prof. CHARLES STEWART, F.R.S., M.R.C.S.

The Members were received in the Entrance Hall of the Museum, at 3 p.m., by Prof. C. Stewart, who at once led the party through some of the new rooms, and in passing gave a very pleasing explanation of some of the preparations, but entered more fully into the structure of the skeleton. The various forms of human skulls, exemplifying those discovered in ancient tombs and prehistoric deposits, were especially dealt with. In the Osteological Gallery attention was directed to the fine skeletons of the gigantic sloths, *Megatherium* and *Mylodon*, and to the skeleton of a large *Dinornis* recently acquired.

In conclusion, Prof. Stewart made some very interesting remarks on Evolution, referring to the skeletons around him in explanation.

After a few words from the President, thanking Prof. Stewart for his interesting and profitable demonstration, the party dispersed through the Museum.

MAY, 1897.]

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY), CROMWELL ROAD.

SATURDAY, MARCH 20TH, 1897.

Director : HENRY WOODWARD, LL.D., F.R.S., F.G.S.

(Keeper of the Department of Geology).

THE party, some sixty in number, were received by the Director in the Entrance Hall at 3 p.m., and, before proceeding to the Geological Galleries, Dr. Woodward drew attention to the bronze statue of Professor Sir Richard Owen, K.C.B., executed by Thos. Brock, R.A., which the Memorial Committee have handed over to the Trustees of the British Museum, to be preserved for ever in the building which he exerted himself so many years to obtain for the reception of the Natural History collections he so dearly loved.

The work is executed after photographs taken by Mr. G. R. De Wilde at the old British Museum. The bone in his left hand is copied from the femur of *Dinornis*, a perfect example of the fragment of bone which he received in 1837, and upon which he made the bold declaration that it was the bone of a struthious bird larger than the ostrich, and that such wingless birds would be found in New Zealand. We now know how that prophecy has been fulfilled. The name of Professor Owen will always be a cherished memory with members of the GEOLOGISTS' ASSOCIATION, whose visits to the Museum he did so much to make interesting and instructive to them.

Dr. Woodward introduced the members to the Cephalopod Gallery, which had been arranged almost entirely by Mr. G. C. Crick, F.G.S., who, together with Mr. A. H. Foord, was preparing a series of catalogues of this class. The Gallery (No. VII.) is entirely devoted to the CEPHALOPODA save one case, which contains such doubtful forms as *Conularia*, hitherto referred to the PTEROPODA, but not now considered to belong to that group. The first two wall-cases contain the Dibranchiata (Cuttle-fishes, Squids, Calamaries, and the Argonaut), the first table-case being intended to illustrate the chief points of interest in the class, both Dibranchiate and Tetrabranchiate forms. There is also a small case between wall-cases 1 and 2 devoted to illustrations of recent forms, preserved in spirits, to show the soft parts of the animals.

Eighty-six diagrams are placed around the tops of the wall-cases to illustrate the various forms of shells peculiar to this group.

[JULY, 1897.]

upper part of the hill is composed of Eocene Beds, which form a small outlier about three-quarters of a mile long by half a mile in width, and on them there is a small capping of drift.

Three sections were visited, two on the east and one on the west side of Cowcroft. On arrival at the first section, the Director made a few observations on the geology of the locality. He remarked that Cowcroft was one of a line of Eocene outliers which run parallel to the northern boundary of the main mass of the Tertiary strata, that is, in a north-east and south-west direction; and he thought they were all probably due to a line of slight change of dip, which passed through Woodcote Common, near Goring, Nettlebed Hill, Turville Common, Lane End, Tyler's Hill, and Bennet's End. This had been suggested by Mr. Whitaker,* and evidence in support of this contention had been pointed out by the Director on the occasion of the Excursion to Wendover, May 14th, 1892.†

These outliers are nearly always capped by pebble gravel, the Westleton Shingle of Professor Prestwich, and are frequently connected with trough faults whereby Tertiary Beds were protected from denudation.

In the first section, at the north-east corner of the brickfield, the whole of the Reading Beds were exposed, about 25 feet in thickness, the lower portion consisting of grey, mottled, laminated sandy clay, the upper of very white sand, indurated in parts. At the base is a layer of about 6 inches of green-coated unwater-worn flints and pebbles, reposing on a level surface of chalk, which has been excavated to a depth of about 15 feet, but presents no features of importance. This section is capped by the Basement Bed of the London Clay which is 3-5 ft. thick, but owing to the recent heavy rains could not be examined.

The second section, at the S.E. corner of the brickfield, shows the Chalk fretted away in pinnacles, two of which were visible. These pinnacles are invested with a dark layer, consisting of unworn flints in clay mingled with pebbles and broken shells, surmounted by Brick-earth, which thickens towards the S., extending downwards far below the level of the base of the pinnacles. In the upper portion of the Brick-earth masses of conglomerate and irregular layers of flint and quartz pebbles are found, the latter parallel to the top of the Chalk, though not resting upon it. Mr. Monckton suggested that the position of the Brick-earth was due to a large pipe or swallow hole in the Chalk into which a mass of drift had sunk.

The third section is at the S.W. corner of the outlier, and shows about 15 ft. of Woolwich and Reading Beds, the lower portion of these and the junction with the Chalk not being

* *Geol. of London*, vol. i, p. 484.

† *Proc. Geol. Assoc.*, vol. xii, p. 349.

visible. These beds consist here of 7-8 ft. of Buff Sands, with irregular pipe-clay partings passing upwards into bright-red mottled sands 4 ft., and another 4 ft. of white sand, mottled red. Above these occurs the Basement Bed of the London Clay, consisting of a very well-marked line of flint pebbles about 6 inches in thickness, in which *Lamna* teeth were found. Covering this, there is about 12 ft. of evenly-stratified laminated sandy clay, with a more or less continuous line of flint pebbles, and from this bed many large calcareous blocks containing fossils had been extracted. None of these were, however, seen *in situ* on this occasion. The following fossils were identified :

Ditrupa plana, Sow.
Cardium laytoni, Mor.

„ sp.
Cytherea sp.
Glycimeris rutupiensis.
Nucula ?

Panopæa intermedia, Sow.
Pectunculus brevirostris, Sow.
Fusus ficulneus, Desh.

„ sp.
Melania sp.
Natica sp.
Pyrula sp.

Leaving Cowcroft, the party proceeded in a south-westerly direction across the valley of the Chess to a chalk-pit at Aldridge's Dell. In this pit the Chalk Rock is seen. It does not, however, appear to be very fossiliferous ; but after a time one of the members found a moderately good specimen of *Terebratula semiglobosa*. The Director had, some few days before the excursion, found *Vermicularia*, *Rhynchonella reedensis*, Eth., *Arca*, *Limopsis*, *Lima spinosa*, Sow., and *Trochus*. The party then returned to Chesham, where they partook of an excellent tea at the Chess Vale Hotel. After tea Mr. Monckton proposed a vote of thanks to the Director, which was carried by acclamation, and the party returned to London.

It may be of interest to note that the only previously recorded excursion of the Association to Tyler's Hill took place on May 18th, 1878, under the direction of Dr. (now Sir) John Evans and Mr. Hopkinson. It was a half-day excursion, and as there was at that time no railway to Chesham the party travelled to Boxmoor Station and drove from there to Tyler's Hill.

REFERENCES.

Geological Survey Map, Sheet 7 (Drift Edition, 1871). Price 18s. 6d.
 Geological Survey Index Map, Sheet 12. Price 2s. 6d.
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EXCURSION TO AYLESBURY, HARTWELL,
AND STONE.

SATURDAY, APRIL 10TH, 1897.

Directors: A. M. DAVIES, B.Sc., F.G.S., and
PERCY EMARY, F.G.S.

Excursion Secretary: H. A. ALLEN, F.G.S.

(*Report by THE DIRECTORS.*)

ABOUT twenty-three members assembled at Aylesbury (Metropolitan Railway) shortly after 3 p.m., and were led without delay along a field-path to Locke’s clay-pit, on the Thame road, about a mile and a quarter out of Aylesbury. Here Mr. Davies briefly explained the objects of the excursion. It was nearly ten years, he said, since the Association had visited this district, which was probably new ground to many present. To the east and south the Chalk escarpment of the Chilterns was conspicuous. The vale at the foot of it was marked on the geological map as occupied mainly by Gault and Kimeridge Clays, between the outcrops of which two clays came an apparently irregular and discontinuous series of patches mapped as Portland Sand, Portland Stone, Purbeck, and Lower Greensand. The ground on which they were then standing was mapped as Kimeridge Clay, but the fossils which had made this pit famous indicated a higher horizon than the highest proper Kimeridgian, and though for mapping purposes it was impossible to separate it from Kimeridge Clay, it was better to speak of it as Hartwell Clay, and to include it, as Mr. JULY, 1897.]

H. B. Woodward did in the Lower Portlandian. Professor Pavlow, in his recent paper,* with further and taken a Middle Portlandian.) It followed that the beds marked as Portlandian Sand in this district did not represent the horizon known by that name in the southern counties. The bedding with the Portland Stone above, were Upper Portlandian.



FIG. 1.—GEOLOGICAL SECTION MAP OF THE DISTRICT FROM AYLESFORD TO STONE.

1/4 in. = 100 yds. scale.

Scale 1 inch = 1 mile.

Notes on the map: Aylesford and Stone.

Exposures traced—1. There are a few small exposures of the Lower Portlandian in the district, but the only one of any importance is the large one at Aylesford, where the stone is quarried. The stone is a fine, white, crystalline limestone, and is used for building purposes.

The President Mr. E. T. Newton, taking occasion to remark that a collection of shells from these hills had been made many years ago by the late Dr. E. Lee, which included many species of a peculiar type and beautifully preserved. These shells are now preserved in Dr. Lee's museum at Aylesford.

The spoils were not in any great quantity, but a number of the characteristic fossils were obtained, including:

* Quart. Jour. Geol. Soc. London, vol. 42, p. 100, 1886.

Arca longipunctata, Blake.
Asiarte hartwellensis, Sow.
 „ *mysis*, d'Orb.
Modiola pectinata, Phil. non Sow.
Pecten lens, Sow. var. *morini*, de Lor.
Perna mytiloides, Lam.
Pholadomya proteii, Ag.
Thracia depressa, Sow.
Trigonia voltzii?, Ag.
Ammonites (Perisphinctes) biplex, Sow.
Belemnites explanatus, Phil.

The Thame road was next followed for nearly a mile, when another pit was reached. This lies a little beyond the “Bugle Horn” Inn, and has therefore become known as the “Bugle Pit.” By some curious slip it has twice been referred to in geological literature as the *Beagle* Pit.*

The succession of the beds here was pointed out by Mr. Emary. The beds seen were those shown on the accompanying section (Fig. 2), from the top down to and including the gritty limestone, No. 5. The sand bed, No. 4, and the rubbly limestone, No. 3, were exposed in a pit sunk at this spot when the Association visited Hartwell in 1887.† The limestone, No. 3, is here almost unfossiliferous, but is believed to be the equivalent of a very fossiliferous bed, which was exposed at the town of Aylesbury when the drainage works were being carried out. Mr. Emary called attention to the fact that Ostracods have been recorded by Prof. Rupert Jones‡ from this locality, not only in the Purbeck beds but also in the upper bed of the Portland No. 9. It is interesting to learn that some of the forms described from this bed are marine, whilst others are freshwater. There is a similar mingling of marine and freshwater forms in the lower part of the Purbeck beds, whilst in the upper part freshwater forms only are met with. This appears to indicate a gradual transition from the marine conditions of the Portland to the freshwater conditions of the Purbeck episode, and that the two series are conformable to each other in this district. There is, however, a considerable amount of erosion in the Purbeck beds themselves, the marly beds with limestone bands being scooped out into hollows, occupied by a greyish clay.

The fossils recorded from the Purbeck beds of this district include several species of *Cyrena*, *Paludina (Vivipara)*, etc., together with fish remains, plants, and insects. Unfortunately no record appears to have been made of the exact horizon from which they were obtained, *i.e.*, whether above or below the line

* *Quart. Journ. Geol. Soc.*, vol. xlix, p. 566; *Proc. Geol. Assoc.*, vol. xiv, p. 31.

† *Proc. Geol. Assoc.*, vol. x, p. 169.

‡ *Quart. Journ. Geol. Soc.*, vol. xl p. 328.

1. **Salmon**

THE UNITED STATES DEPARTMENT OF THE INTERIOR
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of erosion. More detailed work is therefore needed before the age of the upper clayey beds, above alluded to, can be regarded as settled. With regard to the marly beds, reference was made to the view of Prof. Blake, namely, that they are the freshwater equivalent of the marine Portland Stone of the coast. Prof. Blake correlates the creamy limestones of Hartwell with the *Trigonia* beds of Swindon, and with the lower part of the flinty series of the Isle of Portland. This would leave the remainder of the flinty series and the whole of the building stone series of the Isle of Portland unrepresented here unless they are represented in part of the marly beds mapped as "Purbeck." A number of casts of *Trigonia* were obtained by members of the party, and *Cardium dissimile* was found to be very abundant. Several fish scales and vertebræ were found in the "Pendle," and one of the large Ammonites so common in the district (*Perisphinctes boloniensis*) was seen *in situ* in the creamy limestone.

Those members who could be induced to tear themselves away from this famous fossil locality were now conducted along the road for another half-mile or so to what may be referred to as the "Old Sandpit," Stone, for want of a more accurate name. Accuracy, however, is very needful in dealing with a series of beds so changeable as these sands, and it is most regrettable that some of the sections described by Fitton and Morris are very difficult to localise now. It may, therefore, be advisable to state that this is the pit distinctly marked on the six-inch map, almost opposite "Stone Farm," and extending northwards from the road half-way to a little coppice.

The section here shows 9 feet of sand, pure white for the most part, but slightly carbonaceous in places. Above this comes 2 feet of clay (including beds of clayey sand); and at the eastern end of the pit there comes on above this a very distinct bed of pebbly carstone, consisting of pebbles of quartz and "lydite," firmly cemented by iron oxide.

Mr. Davies here explained that these sandy beds were mapped as "Lower Greensand," but they might be of any age between the "Purbeck" and the Gault. Ten miles to the north-east began the regular outcrop of the marine sands, whose fossils proved them to be of undoubted *Aptian* age (*i.e.*, of the age of the Hythe, Sandgate, and part of the Folkestone beds, and the Tealby limestone). The same fossils had been found fifteen miles to the west-south-west, at Toot Baldon. But between these two points came a series of scattered outliers of sands, in some of which (as at Shotover and Brill) freshwater fossils, possibly of Wealden age, had been found.

Mr. Teall long ago called attention to the fact that these scattered patches rested upon Portland or Purbeck, while the marine sands rested on Kimeridge or on Oxford Clay, and he suggested that there were two distinct series here—an older fresh-

NOTES ON THE MICROZOA FROM THE JURASSIC BEDS AT HARTWELL.

By FREDERICK CHAPMAN, A.L.S., F.R.M.S.

HAVING been favoured some years ago with fossiliferous material from Hartwell by Thos. Barron, Esq., F.G.S., and more recently by E. E. L. Dixon, Esq., who, in fact, collected some samples on the occasion of the last excursion of the Association to Hartwell, I have drawn up the following lists of the Microzoa obtained from these samples, since they present some special points of interest.

Ostracoda from the Lower Purbeck, Bugle Pit, Hartwell :

- Cypris purbeckensis*, Forbes. Very common.
 „ „ var. *reniformis*, Jones. Rare.
Candona ansata, Jones. Common.
 „ *bononiensis*, Jones. Frequent.
Cypridea punctata (Forbes).* Rare.
Metacypris forbesii, Jones.† Very rare.
Cythere retirugata, Jones. Common.
 „ „ var. *textilis*, Jones. Frequent.

The sandy and glauconitic Hartwell Clay contains a few Ostracoda and Foraminifera of much interest, which present a facies nearly comparable with that of Neocomian strata as far as it is known, and also in some respects comparable with that of the Gault.

The list given below is preliminary to some further and more detailed work upon which I am engaged with regard to beds of similar age in this and other localities.

Ostracoda from the Hartwell Clay.

Cythere drupacea, Jones, 1884, *Quart. Journ. Geol. Soc.*, vol. xl, p. 772, pl. xxxiv, fig. 30. *Cytheropteron drupaceum*, Chapman, 1894, *Quart. Journ. Geol. Soc.*, vol. l, p. 691. This form has been described from the Great Oolite beds of the Richmond Well boring, and from the Neocomian (Bargate) beds near Guildford. Judging from the example now found, this species appears properly to belong to the genus *Cythere*, and not to *Cytheropteron*.

Cytheridea subperforata, Jones, 1884, *Quart. Journ. Geol. Soc.*, vol. xl, pp. 768 and 772, pl. xxxiv, figs. 25 and 26. Chapman, 1894, *Quart. Journ. Geol. Soc.*, vol. l, p. 689. Like the preceding, this species was originally described from the Rich-

* Recorded by Prof. T. R. Jones from the Middle and Upper Purbecks. *Quart. Journ. Geol. Soc.*, vol. xli (1885), pp. 332 and 335.

† Previously noted as "Rare and peculiar to Middle Purbeck." Prof. T. R. Jones, *Quart. Journ. Geol. Soc.*, vol. xli (1885), p. 336; also p. 332.

mond Well boring, and was found in the junction-bed of the Oolite and (?) Neocomian. It was latterly found in the Neocomian (Bargate) beds near Guildford.

Foraminifera from the Hartwell Clay.

Tritaxia (?) *variabilis*, Brady.

Lagena lævis (Montagu).

Nodosaria raphanus (Linné).

Marginulina (?) *jonesi*, Reuss.

Vaginulina discors, Koch.

„ *harpa*, Römer.

Cristellaria italica (Defrance).

„ *navicula*, d'Orb.

„ *sulcifera*, Reuss.

„ *humilis*, Reuss.

„ *fragaria* (Gümbel).

„ *gibba*, d'Orb.

„ *convergens*, Bornemann.

„ *cultrata* (Montfort).

Globigerina marginata (Reuss).

EXCURSION TO WALMER, ST. MARGARETS, DOVER, FOLKESTONE, AND ROMNEY MARSH.

EASTER, 1897.

Directors: GEORGE DOWKER, F.G.S., W. F. GWINNELL, F.G.S.,
DR. A. W. ROWE, F.G.S., and C. DAVIES SHERBORN, F.Z.S.

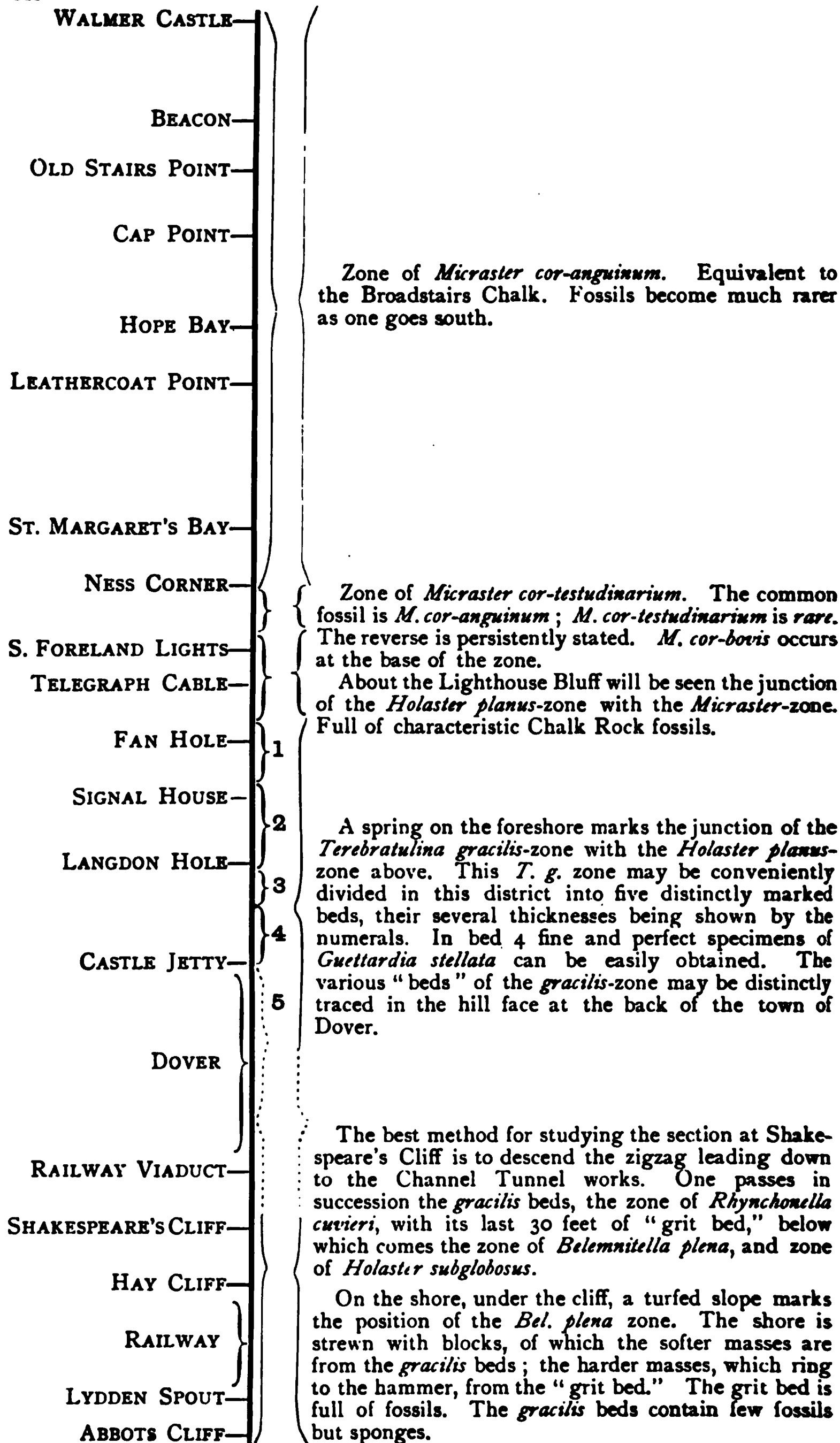
Excursion Secretary: E. P. RIDLEY, F.G.S.

(Report by DR. ROWE and MR. SHERBORN.)

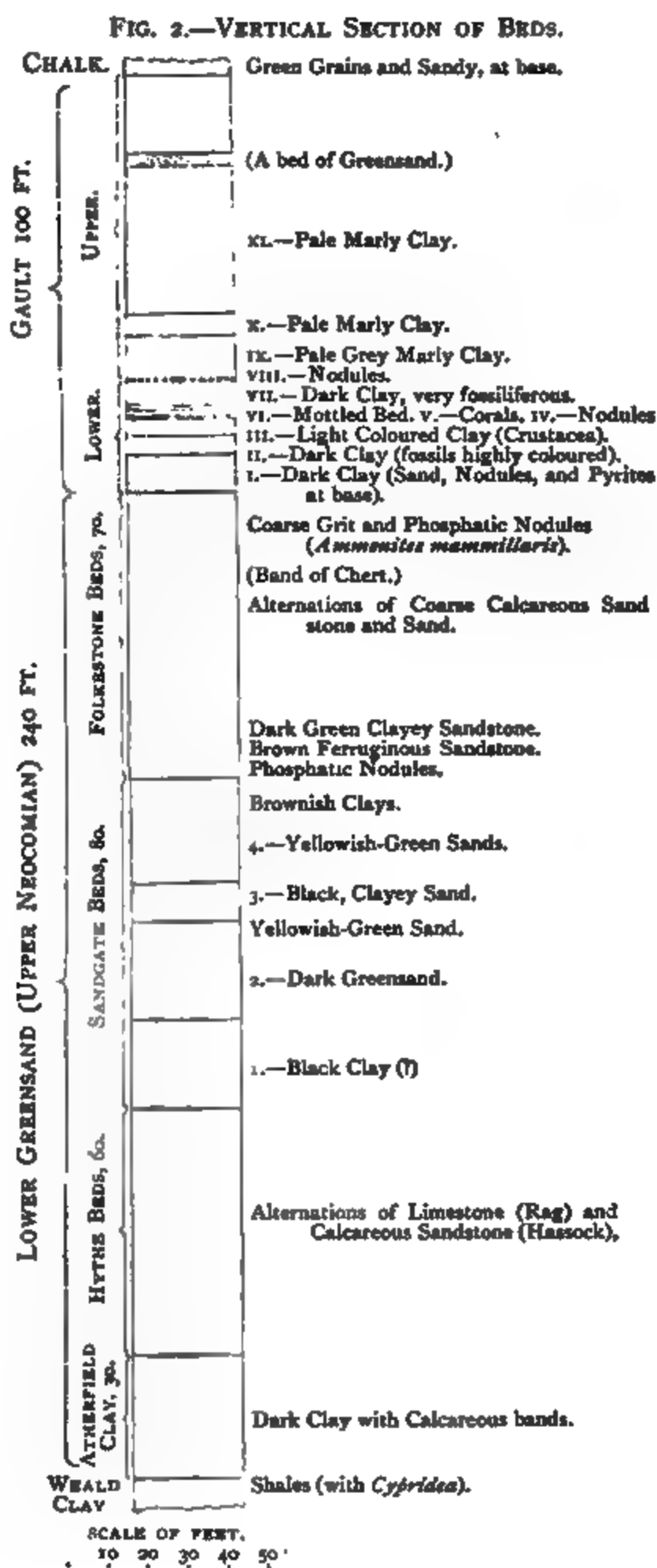
Friday, April 16th, and Saturday, April 17th.—Dr. A. W. Rowe, M.R.C.S., F.G.S., and C. Davies Sherborn acted as Directors.

The party took the train to Walmer and walked through the picturesque old town to the sea. Turning south towards St. Margaret's Bay, collecting all the time, the members noted the very variable distribution of organic remains in this portion of the *Micraster cor-anguinum*-zone. That part of the cliff above the grassy slope is fairly rich, while that part along the shore after passing the grassy slopes is comparatively barren. Proceeding next morning to St. Margaret's Bay, over the downs from Dover,
JULY, 1897.]

N.



PLAN OF OUTCROPS ON SHORE-LINE BETWEEN WALMER CASTLE AND ABBOTS CLIFF, DOVER.—Arthur W. Rowe and C. Davies Sherborn.



SECTIONS ILLUSTRATING THE GEOLOGY OF HYPHE, SANDGATE, AND FOLKESTONE.

the members joined up the previous day's work and entered at once into the so-called *Micraster cor-testudinarium*-zone, first seen on the shore about the middle of St. Margaret's Bay. After waiting several hours on account of the rain and high tide, the Ness corner was rounded and the junction of the *M. cor-anguinum* and the *M. cor-testudinarium*-zones shown, and the party then proceeded towards Dover, collecting as they went, and passed successively over the *Holaster planus*-zone, including the Chalk Rock and the upper part of the *Terebratulina gracilis*-zone. The plan of outcrops here given completely expresses these two days' work.

A visit was paid to the Channel Tunnel Works and the Kent Coal Boring.

Monday, April 19th.—Mr. W. F. Gwinnell acted as Director. The party travelled by S.E. Railway to Shorncliffe Station, and after a short walk arrived at a brickpit in the Gault, where many fossils were collected. A visit was then paid to the Waterworks, and Lower Greensand fossils were obtained from blocks thrown out of a well-sinking. Whilst some of the more daring of the party made an excursion underground to see the workings, others made good collections of Lower Chalk *Ammonites*, etc.

After visiting Cæsar's Camp, the party proceeded to East Wear Bay and the Warrens, where fossils were plentiful and good "bags" were made. The party returned by train to Dover.

Tuesday, April 20th.—Mr. G. Dowker acted as Director. The party, numbering twenty-eight, took train to Hythe, and drove to Lympne Castle and church, situate on an escarpment of the Lower Greensand. From this elevation the Director explained the history of the formation of the Marsh as given in his paper read on the 2nd April, 1897. On descending the hill the *Castrum* was examined and special attention directed to some of the walls, which are said to have slipped some distance down the hill. The carriages were met at Botolph's Bridge, and the party proceeded to Littlestone, a halt being made at Dymchurch to examine the sea-wall. After lunch at Littlestone, the party proceeded by train to Appledore, the vast extent of the Dungeness shingly beach being well seen in passing. On arrival at Appledore a visit was paid to the Rhee Wall, and the train taken for home.

REFERENCES.

Geological Survey Map, Sheets 3 (Drift Edition), price 8s. 6d. ; and 4 (Solid) price 5s.
Ordnance Survey Map (New Series), Sheets 290, 305, 306, 321. Price, 1s. each.

1836. FITTON, W. H.—"On the Strata below the Chalk." *Trans. Geol. Soc.* Ser. 2, vol. iv.

1864. DREW, F.—"The Geology of the Country between Folkestone and Rye." *Mem. Geol. Survey.*
1874. HILTON PRICE, F. G.—"Gault of Folkestone." *Quart. Journ. Geol. Soc.*, vol. xxx.
1874. ————"Lower Greensand and Gault of Folkestone." *Proc. Geol. Assoc.*, vol. iv.
1875. TOPLEY, W.—"Geology of the Weald." *Mem. Geol. Survey.*
1886. HILL, WILLIAM.—"The Beds between the Upper and Lower Chalk of Dover." *Quart. Journ. Geol. Soc.*, vol. xlii, p. 232.
- For Reports of former Excursions, see "Record of Excursions," pp. 66-74.

EXCURSION TO COOKHAM

SATURDAY, MAY 1ST, 1897.

Director : LL. TREACHER, F.G.S.

Excursion Secretary : H. A. ALLEN, F.G.S.

(*Report by THE DIRECTOR*).

THE party met at Paddington, and travelled to Cookham by the 1.40 p.m. train, and on arrival at once proceeded to Cookham Rise, where the Director pointed out the terrace-like arrangement of the river gravels in the Thames Valley between Cookham and Maidenhead.* From this point three distinct terraces could easily be distinguished. In the upper one, on which they were standing, a large number of pits have been opened between this place and Maidenhead, and in nearly all of them Palæolithic implements have been found. Those in the Director's collection number over 300, obtained during the last eight or nine years. They are met with at all depths in the gravel, those from near the surface having a white and porcellanous appearance, while others from the bottom of the gravel near the Chalk are quite sharp and fresh looking. Some specimens are much abraded, as if they had been rolled about for a long time. The commonest types are the shoe-shaped and an axe-like form with a straight cutting edge, but nearly every type of Palæolithic implement is represented, and flakes are also found. Organic remains are rare in this terrace, but a large tusk of Mammoth was found with flint implements in a pit near Maidenhead. As the implements appear to be almost entirely confined to this terrace, at a level of about 150 ft. O.D., and about 75 ft. above the present river, it may be taken as constituting the Palæolithic zone of the Thames Valley gravels in the district. The large pit at Cookham Rise, belonging to Mr. Symmons, of Maidenhead, was then inspected, and the presence of large quartzite pebbles and blocks of sarsen stone, of white quartz, and of sandstone was noted. The gravel was observed to rest in a sort of furrow in the Chalk, having a

* See the Sketch Map in Whitaker's *Geology of London*, vol. i, p. 391.

north and south direction parallel with the river, and its thickness varied from 2 to about 14 ft. Under some houses built close to the pit no gravel had been found, although the surface level was the same as where the gravel was thickest.

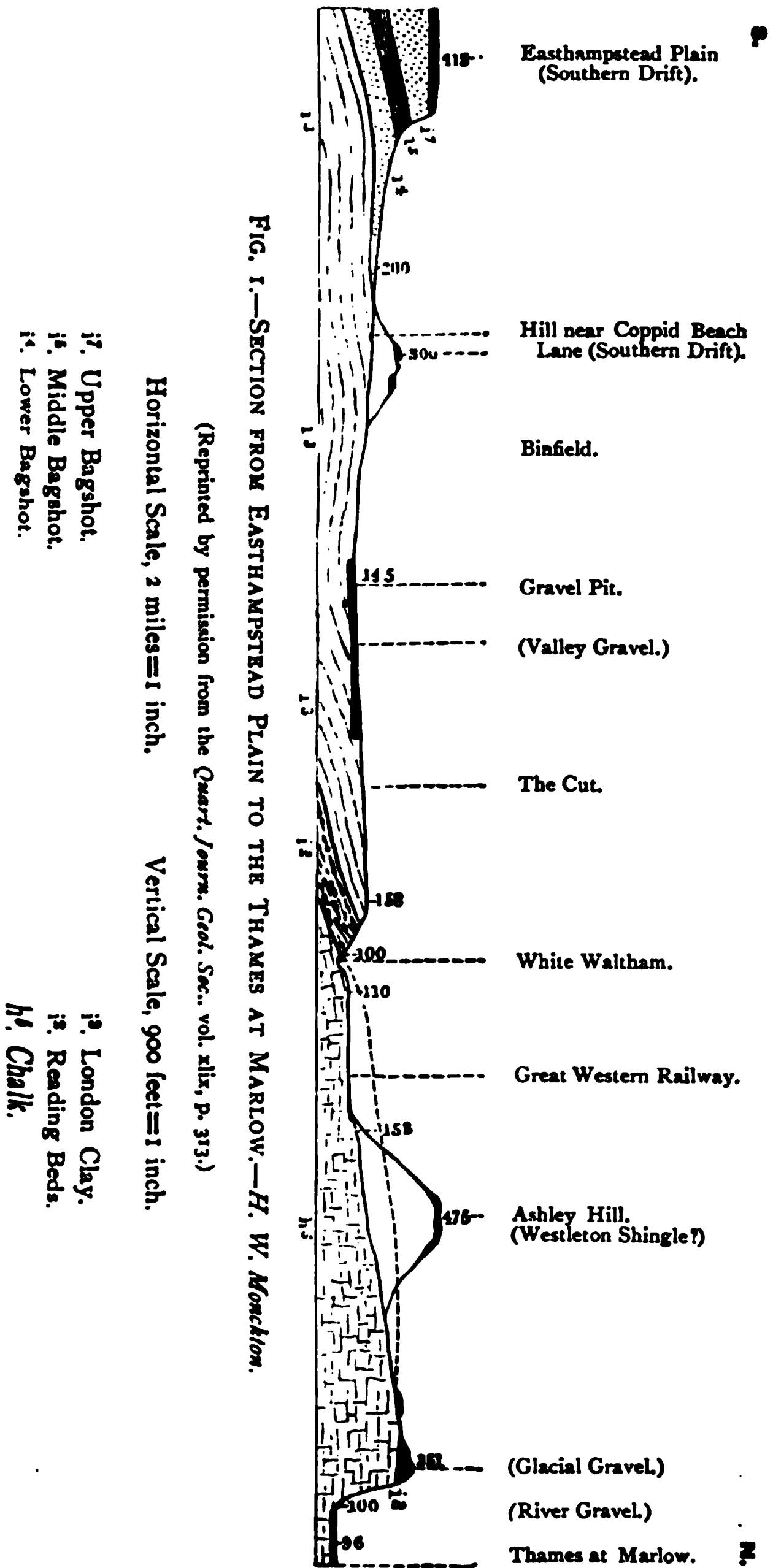
A move was then made to the large chalk pit at Cookham Dean. This is an exposure of Upper Chalk about 70 ft. in depth. Flint bands are numerous, and contain abundant remains of sponges. From Mr. Whitaker's account,* it would appear to belong to the *Micraster cor-testudinarium* zone. Only a short stay was made here, and but few fossils found.

Cookham Dean is a small village situated in a narrow, gorge-like valley cut through the high Chalk hills which form the north-east corner of Berkshire. This little valley has a general course from west to east nearly parallel to the Thames between Marlow and Bourne End, from which it is only divided by the Quarry Wood ridge, it commences in the open country north-west of Pinkney's Green, and joins the Thames at Cookham. As there is now no stream along its bottom it probably had its origin when the country to the west was covered with impervious Tertiary clays, the surface drainage of which would naturally form such a valley in making its way to the Thames. At present the rainfall gets away by underground channels and fissures in the chalk, whilst the bed of the valley is left dry.

A footpath was then followed for some distance along the valley to the westward, and the hillside on the north ascended by a green lane to the "Hockett." Mr. Stephen Darby, of Cookham Dean, who accompanied the party and materially assisted to make the excursion a success, suggested that this word simply meant the High Wood. The summit of the Quarry Wood ridge was here reached. It is a small outlier of Tertiary Beds capped by a deposit of gravel, the character of which was shown in a somewhat overgrown pit in a field by the side of the wood. The party rested for some time at this place, and the Director briefly pointed out the chief geological features of the neighbourhood. Looking towards the south the Chalk plain was observed to have a gentle inclination along the dip-slope from the foot of the hill on which they were standing southwards to the main Tertiary escarpment on the other side of the White Waltham Valley. On the left hand were the Tertiary outliers of the Mount and Pinkney's Green standing well up from the surface of the Chalk, and on the right, but at a greater distance and somewhat hidden by the mist, were the similar outliers of Ashley and Bowsey Hills, these latter being capped at a height of about 460 feet O.D. by a deposit of the pebbly gravel generally known as the Westleton Shingle.

Mr. Monckton expressed an opinion that the gravel at the

* *Geology of London*, vol. i, p. 76.



Hockett ought to be classed with the Glacial Gravel, which occurred at various levels up to rather over 400 feet O.D., on hills on the other side of the river Thames. The gravel contained far too many red quartzite pebbles for one to place it with the Westleton Shingle or Southern Drift, and on the other hand it bore the greatest resemblance to what has been termed the Glacial Gravel. Referring to the diagram section, Fig. 1, the speaker explained that the gravel pit of the Hockett was at the point marked "351 Glacial Gravel," and said he thought that if he was right in calling the gravel Glacial Gravel, there was a strong probability that the Thames valley at Marlow had been wholly excavated since the date of that gravel, and if so, then at that date either :

- (1) The Thames flowed at what is now a level of 350 feet O.D. or thereabouts ; or
- (2) The Thames flowed in some other channel ; or
- (3) The Thames did not exist.

He himself was in favour of the first of these conclusions.

Search was then made in the pit, and large quartzite pebbles and blocks of white quartz and other rocks characteristic of the gravel mapped Glacial Drift north of the Thames were easily found. The Director also dug out of undisturbed gravel, at a depth of 3 feet from the surface, a flint flake showing evident signs of human workmanship.

On leaving this spot, the party proceeded by the footpath through Quarry Woods to the top of Winter Hill, where they obtained a fine view of the Thames Valley near Marlow, and of the Chiltern Hills to the north. The Tertiary outlier of Lane End was very conspicuous about six miles away on the north-west. The eastern end of Winter Hill is covered by a patch of river gravel at a height of 250 feet O.D., but no sections were open on this occasion. Cock Marsh was then crossed by the rifle range to the Quarry Hotel, where tea was partaken of, and the Director received a hearty vote of thanks from the members present. Having been ferried over the river, the party returned to town by the 6.50 train from Bourne End Station.

REFERENCES.

Geological Survey Map, Sheet 7 (Drift Edition). Price 18s. 6d.
Ordnance Survey Map (New Series), Sheet 255. Price 1s.

1889. WHITAKER, W.—"Geology of London," vol. i, pp. 76, 301, 389. *Mem. Geol. Survey.*
1893. MONCKTON, H. W.—"Boulders, etc., from the Glacial Drift." *Quart. Journ. Geol. Soc.*, vol. xlix, p. 312.
1896. OSBORNE WHITE, H. J.—"Westleton and Glacial Gravels in Oxfordshire and Berkshire." *Proc. Geol. Assoc.*, vol. xiv, p. 23.

EXCURSION TO TUNBRIDGE WELLS

SATURDAY, MAY 8TH 1897.

Director: GEORGE ABERT, M.A.C.S.

Excursion Secretary: A. C. VINTAGE, F.C.S.

Report by THE DIRECTOR

THE excursion commenced by a visit to High Brooms Brickyard, close to Southborough Station, where Wadhurst Clay (100 feet) capped with lower beds of Tunbridge Wells Sands (20 feet) are worked together for brick-making. The members soon found specimens of *Cyrena media*, *Cypris rubicundus*, *Equisetites lyellii*, and a tooth of *Lepidodactylus*. The blue clay contains only a few calcareous septarian nodules, which generally show more or less trace of fossils. The lower beds, owing to the presence of veins of calcite, are not worked, but are exposed in drainage channels.

A short walk to Shatters Wood Road, and a section of Tunbridge Wells Sands (top beds) was seen. The beds here, owing to the removal of iron, are soft and easily crushed into building sand.

The party next made its way to the boring for water on Southborough Common. This boring has reached a depth of 296 feet. Specimens of beds passed through were shown by Messrs. Islers' Engineer (Mr. Shreeve), to Mr. W. Whitaker, F.R.S., who considered that the fine white sands now being brought up must be from the Ashdown beds.

After a pleasant walk of about a mile, Strange's Quarry, near Broomhill, was reached, where the upper beds of the Tunbridge Wells Sands are worked and used for Building Stone. The sandstone here is covered by an outlier of Weald Clay. At the bottom of the clay are three or four hard layers, hardened probably by a re-deposition of carbonate of lime, while the upper portion is worked for brick-making. Mr. Abbott pointed out that the Weald Clay at this spot differs from that at Mount Ephraim, which is quite free from these hard beds. The stone in this quarry contains plenty of iron, and but little, if any, bleaching has gone on. Possibly this may be due to the thick protecting cap of Weald Clay. *Cyrena media*, *Unio antiquus*, *Cypris tuberculata*, and *Cypris spinigera* were found in abundance near the floor of the quarry, some 10 feet to 15 feet below the top of the Tunbridge Wells bed.

A picturesque, water-worn valley on Culverden Down was next visited. On either side the Tunbridge Wells Sands showed much weathering (honeycombing). On the higher level or "down" the growth of rushes was pointed out, demonstrating

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the difficulty which rain-water finds in passing through such fine-grained sandstone—a great proportion finds it easier to run off the ground, forming side valleys, than to go through the rocks.

The description of what was next seen in Boyne Park need not be repeated, as it was reported in last year's PROCEEDINGS, vol. xiv, p. 198.

Mr. Stocks having since then examined the "black band," his report is appended.

At 4.30 an adjournment to Nye's on Mount Ephraim for tea gave a welcome opportunity for a rest.

Afterwards the party divided; the larger portion saw the exposed "Rocks" on Tunbridge Wells and Rusthall Commons. Much interest was taken in the horizontal rows of holes occurring along the planes of bedding in some of these rocks; apparently due to percolating water assisted, possibly, by the action of frost.

A short visit was paid to the "High Rocks," where similar holes were seen, and a discussion took place on the origin of the remarkable perpendicular jointing of these Rocks. A brief inspection, in a new road near Cumberland Walk, of a section of Clay (? East Grinstead Clay) in which large angular fragments of sandstone lie in most irregular order, brought the excursion to an end.

NOTE ON A DARK COLOURED BAND IN THE TUNBRIDGE WELLS SAND AT BOYNE PARK.

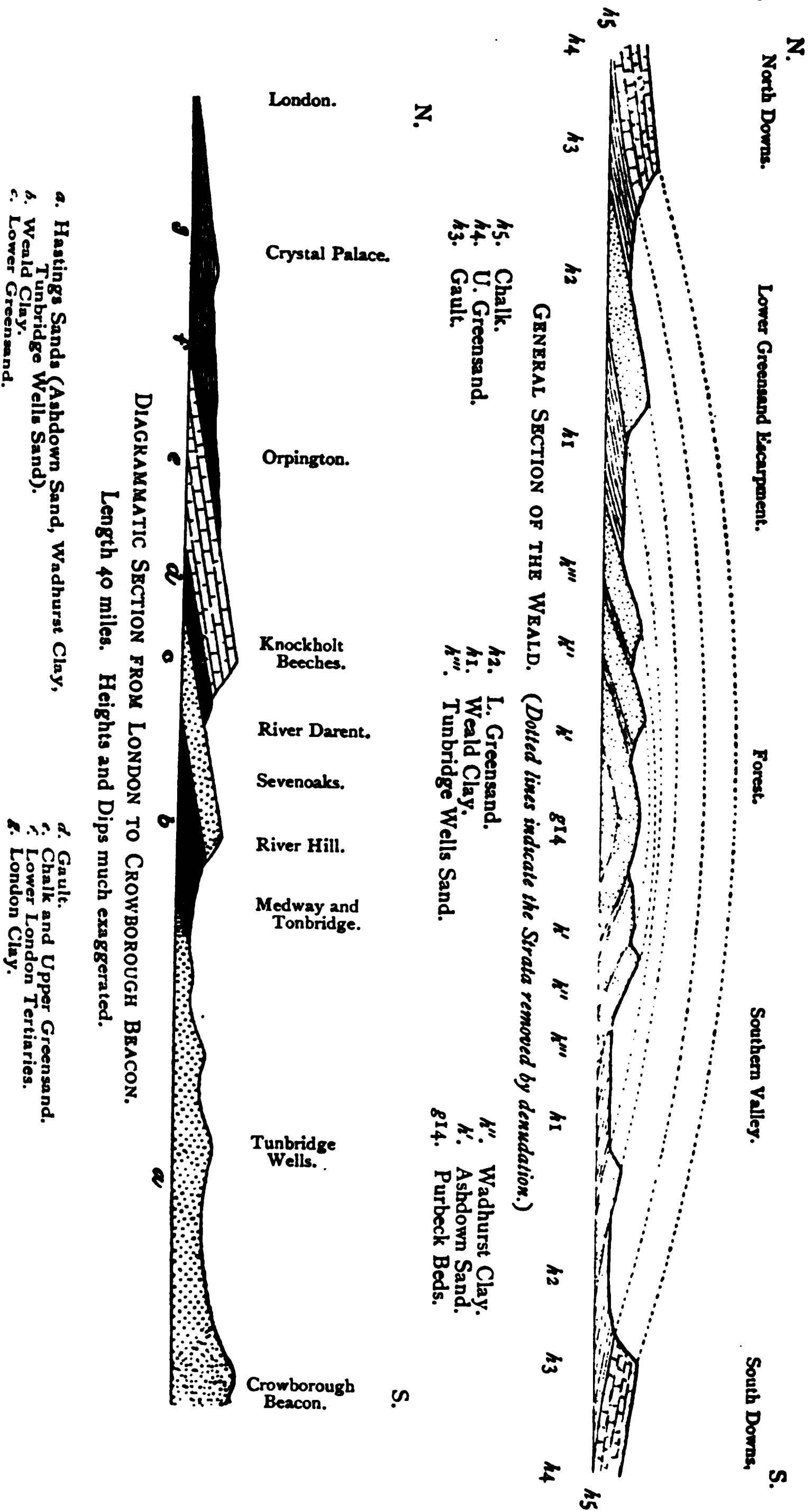
BY H. B. STOCKS.

ON testing a portion of the dark-brown and black sand from Boyne Park it was found that the colouring matter is not extracted by hydrochloric acid, but is quite soluble in caustic soda, yielding a dark-brown solution, from which hydrochloric acid precipitates a brown flocculent substance.

On igniting the sand the black colour disappears with incandescence, and carbonic acid is formed; therefore the colouring matter is organic, the ignited sand has only a pale reddish-yellow colour. Iron is present only in small quantity, and manganese is absent.

Taking these facts into consideration, it appears that the material colouring the sand is organic matter and of the nature of "humic" acid.

This humic acid is probably derived, by solution in rain water, from the humic acid in the overlying soil and the redeposition of it in certain lines in the strata below. In order to explain the causes for the redeposition of the humic acid, further examination will, however, be required.



REFERENCES.

- Geological Survey Map, Sheet 6 (Drift Edition). Price 8s. 6d.
 Ordnance Survey Map (New Series), Sheets 287, 303. Price 1s. each.
1875. W. TOPLEY.—"The Geology of the Weald." *Mem. Geol. Survey*.
 1879. W. FAWCETT.—"Excursion to Tonbridge and Tunbridge Wells." See
 "Record of Excursions," page 38.
 1895. R. S. HERRIES AND G. ABBOTT.—"Excursion to Tunbridge Wells."
 Proc. Geol. Assoc., vol. xiv, p. 198.
 1896. H. G. SEELEY.—"Note on Current Bedding in Clays." *British*
 Assoc. Report, p. 805.

EXCURSION TO CHISELHURST.

MAY 15TH, 1897.

Directors: W. WHITAKER, F.R.S., AND T. V. HOLMES, F.G.S.*Excursion Secretary*: W. P. D. STEBBING, F.G.S.

(Report by THE DIRECTORS.)

ON arrival at Chiselhurst railway-station the party proceeded in a north-westerly direction along the road close to, but east of, the railway, passing, near the station, a large old Chalk-pit on the right, too much overgrown to be worth visiting. A halt was made at the corner of Camden Park, where the Chalk was once worked by means of horizontal galleries extending for a considerable distance under the Park. These galleries were inspected by members of the Association when Chiselhurst was visited in 1872, the owner having them illuminated for that purpose. They are now too much choked up to be worth entering. The mouths of some of the galleries are still visible, but as building is going on in front of them they will soon cease to be as conspicuous, both from road and railway, as they have been hitherto. Mr. Whitaker drew attention to the compactness of the Thanet Sand, which stands, with a nearly vertical face, above the Chalk, to the fairly even junction of the two formations, to the presence of a marked firm bed in the Chalk (which forms the roof of the galleries), and to the fact that the Chalk has been worked to a greater depth than formerly, and that though the deep part of the pit was a little below the level of the neighbouring stream, yet there was no water in it.

On leaving Camden Park pit the railway was crossed, and recrossed south of the tunnel. Near by the mouth of the tunnel, and east of Elmstead Lane, is the pit in Rockpit Wood, showing the Blackheath Pebble Beds, which the Association was enabled to visit by kind permission of Sir Samuel Scott, Bart. Here, instead of unconsolidated beds of pebbles and sand, the pebble-beds were

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found to be largely cemented into pudding-stone, and the sand into sandstone, the calcareous cement having evidently been derived from the dissolution of shells by the action of infiltrating rain-water. Large numbers of shells still, however, remained undissolved, and many specimens were secured by members present. *Pectunculus* was confined apparently to a certain layer.

Then, taking a southerly course, the party entered Sandridge Park by a new road which, beginning at the old entrance lodge (built of the rock-bed), turns southward, crossing Logston Wood south of which it divides into two branches, one taking a westerly direction while the other turns southward towards Widmore. Before arriving at this junction, a pit showing Blackheath Pebble Beds on the left side of the road was inspected. The special feature of this pit was the presence of a thickness of four or five feet of sand, bedded and sometimes loamy, above the pebble-beds, which were wholly unconsolidated. Mr. Whitaker made a few remarks, saying that the bedded loamy sand suggested the oncoming of the brickearth of Widmore, which had been classed doubtfully as part of the Blackheath Beds. If this suggestion turned out to be true, the doubt will cease.

Taking the road leading to Widmore, the deep pit at Widmore Kiln was passed but not inspected, being disused and its former sections invisible. The next section visited was in Blackheath Pebble-Beds, close to the spot at which the road on the western side of Bickley Park meets with others from the east, the west, and the north-west, a few yards north of Bickley Station. Here a thickness of 18 or 20 feet of pebble-beds was seen, of the ordinary, unconsolidated kind. At the surface in one corner there was a mixture of clay with the pebbles, suggesting a trace of London Clay. The current-bedding in this pit was on an unusually large scale. Dr. Hinde here found a few large pebbles of quartzite which are worth notice, as pebbles other than these are very rare in these beds.

Crossing the railway at Bickley Station, the course taken was easterly. Another pit in Blackheath Pebble-Beds situated in a large field in the angle between the London, Chatham and Dover and South Eastern Railways, was inspected. This section is west of the point at which the railways cross each other, and west of the road from Bickley Park Farm and Chislehurst railway station. Here again current-bedding was well seen, and Dr. Hinde found a quartzite-pebble. These pebbles are of a like character to those the same observer has found in beds of the same age near Croydon, but their origin is uncertain. Dr. Hinde remarked that their occurrence was almost wholly amongst the larger pebbles. Turning to the right on passing under the South Eastern Railway, the footpath north-west of Pond Wood was taken to the village of Chislehurst. There the party was most hospitably entertained by Mr. E. A. Webb, of Cookham Dene. After tea, and the passing

of hearty votes of thanks to Mr. Webb and to the Directors of the excursion, the members returned to London, many visiting on their way to the railway-station the beautiful little village church.

REFERENCES.

Geological Survey Map, Sheet 6 (Drift Edition). Price 8s. 6d.
Ordnance Survey Map (New Series), Sheet 271. Price 1s.

1889. W. WHITAKER. "Geology of London." Vol. i, pp. 115, 116, 227.
Mem. Geol. Survey.

"Record of Excursions," pages 29 to 33.

References to the various papers which deal with the district will be found in the above-mentioned works.

EXCURSION TO ERITH AND CRAYFORD.

SATURDAY, MAY 22ND, 1897.

Director : FLAXMAN C. J. SPURRELL, F.G.S.

Excursion Secretary : W. P. D. STEBBING, F.G.S.

(*Report by MR. MONCKTON.*)

THE party assembled at Cannon Street Station and travelled by the 2.2 p.m. train to Erith. Leaving Erith Station the members were led by the Director to a good section in the lowest gravels of the Brickearth Series at Slades Green. There a short halt was made, and the Director gave an account of the geology of the locality and of the nature and composition of the beds of the Brickearth Series. The members then examined the section and noticed that the gravel showed current bedding in most parts and that, though it consisted mainly of flint, either subangular or in the form of pebbles, both Lower Greensand chert and pebbles of quartz could be found without difficulty. Various other foreign stones occur, and the Director expressed a belief that they were all derived from gravel equivalent to that of Dartford Heath.

The party then proceeded to the classic pit at Crayford which is, unfortunately, not now in a condition altogether satisfactory for the geologist. The main features were, however, pointed out by the Director, but as they have already been fully dealt with in our PROCEEDINGS and elsewhere it is only necessary to refer to the works and references at the end of this report.

Leaving the great Crayford Pit the Director led the way to an exceedingly good section in a pit on the west side of the road to Erith. Here some time was spent, and a number of the characteristic fossils of the Brickearth Series were obtained.

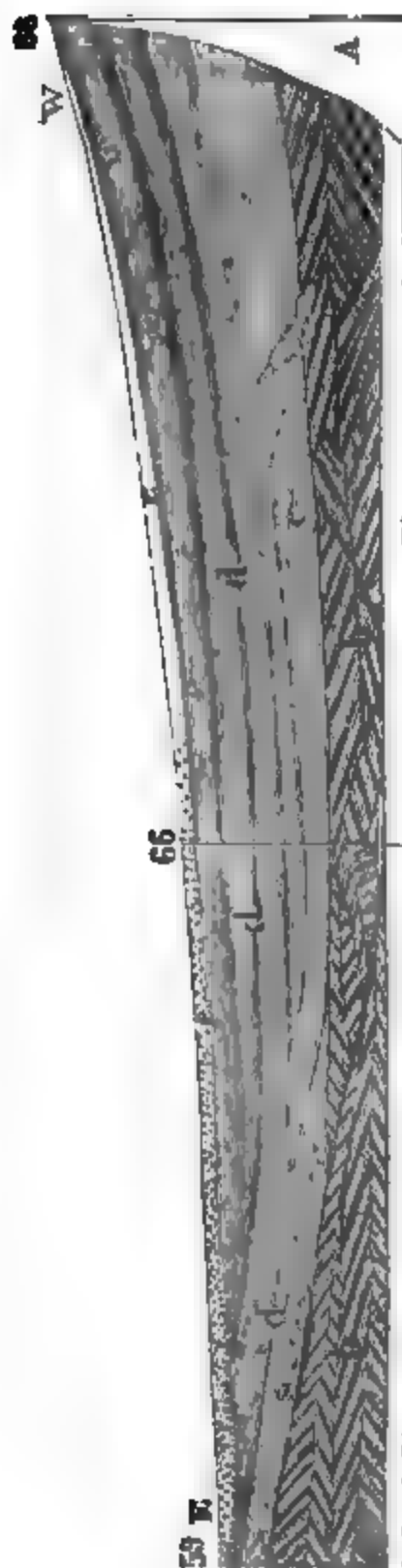
Returning to Erith the members enjoyed an excellent tea at the Prince of Wales Hotel, after which a vote of thanks to the
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SECTION SHOWN BY THE SOUTHERN FACE OF THE GREAT PIT AT THE ERITH BRICKYARD.—W. Whiaker, 1867.

(Reprinted by permission from *The Geology of London*, vol. i, p. 434.)

1. Soil and wash lessening westwards.
2. Brown brick-earth with race about 15 feet ; contains pebbles and pieces of shell from the Woolwich Beds.
3. Darker brown clay, with a little race, about 5 feet, with a little grey brick-earth (with shells) at the bottom passing down into the bed below.
5. Sand with shells, *Cordicula funicularis*, etc., and pebbles less than 4 feet for the most part, loamy at the top in parts, and gravelly at bottom, thins out west.
9. Brick-earth with a little pebble gravel.



SECTION IN THE BRICKFIELD AT ERITH.—A. Tylor, 1869.

(Reprinted by permission from *Quart. Journ. Geol. Soc.*, vol. xxv, p. 85.)

Drift c. Flint Gravel.
 d. Brickearth.

Drift b. False bedded sand.
 A. The Chalk.

Director was proposed by Mr. Potter and carried unanimously. The party returned to London by the 7.6 p.m. train.

REFERENCES.

Geological Survey Map, Sheet 1, S.W. (Drift Edition). Price 3s.
Ordnance Survey Map (New Series), Sheet 271. Price 1s.

1864. J. PRESTWICH.—“Deposits containing the remains of extinct Mammalia and Flint Implements.” *Phil. Trans.*, vol. cliv, Pt. 2. p. 247.
1880. FLAXMAN C. J. SPURRELL.—“On the discovery of the place where Palæolithic Implements were made at Crayford.” *Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 544.
1885. ———.—“Excursion to Erith and Crayford.” *Proc. Geol. Assoc.*, vol. ix, p. 213.
1889. WILLIAM WHITAKER.—“Geology of London.” *Mem. Geol. Survey*.
See also “Record of Excursions,” p. 17.

EXCURSION TO REDHILL AND MERSTHAM (NEW RAILWAY).

SATURDAY, JUNE 26TH, 1897.

Directors: G. J. HINDE, Ph.D., F.R.S., and W. WHITAKER, B.A., F.R.S.

(*Report by THE DIRECTORS.*)

THE party reached Redhill at about 2.30 p.m. The Directors explained that the objects of the Excursion were to trace the succession of the Cretaceous Series from Lower Greensand to Chalk, and to illustrate some difficulties in Geological mapping.

Leaving the station on the eastern side, the party, between sixty and seventy in number, proceeded first to a field about a quarter of a mile distant, where the Fuller's Earth was being excavated. The bed at this place is about fourteen feet in thickness; not the whole of it is, however, economically valuable, and overlying it there are from three to four feet of a sandy rock consisting of quartz and glauconite grains and large numbers of sponge spicules cemented together. Specimens of heavy spar (Sulphate of Baryta) were obtained from the Fuller's Earth, and the overlying sandy sponge rock yielded casts of a small Echinoderm and of *Trigonia*. This same pit was visited* by the Asso-

* *Proc. Geol. Assoc.*, vol. xiii, p. 371.

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ciation three years ago, and, as on that occasion, questions were raised as to the relative position of the Fuller's Earth in the Lower Greensand, and the correctness of the Geological Survey in placing it as the equivalent of the Sandgate Beds. Mr. Whitaker pointed out that the Fuller's Earth formed so marked a feature in the Lower Greensand Series that the Survey was fully justified in considering it as a distinct division.

In an unfinished cutting of the new railway close by, a small disturbance, bringing the Fuller's Earth up to the surface, was noticed, and the footpath northward followed past Wiggy Farm and under the railway to pits at Frenches. At this place beds of brownish drift loam (worked in places for brick-making) with a thin layer of flint gravel at the base, filled up a hollow channelled out of the white Folkestone Sands. In one part of the northern pit the sands were quite up to the surface, whilst in another the loam, eight to ten feet in thickness, reached to the floor of the pit.

A small *Pupa* with fragments of other shells occurred in a whitish marly bed that at one part formed the basal part of the Drift, and also unrecognisable fragments of bone in the loam.

The party then followed Battlebridge Lane northward, and visited the brickyards on the western side of the Lane, where the Drift loam is again exposed, and the bottom beds of the Gault have also been worked for bricks. In the spoil heaps of the Gault Clay, search was made for fossils, and fragments of *Ammonites* (*Hoplites*) *interruptus*, *Belemnites minimus* and a few casts of bivalve molluscs were found. One of the workmen showed phosphatised casts of *Trigonia*, *Inoceramus*, and fragments of *Ammonites*. Phosphatic concretions of glauconite and quartz grains in a dark paste, the coprolites of commerce, are also common in the clay.

Continuing in a north-easterly direction, under the railway at Battlebridge Farm, the next place visited was a pit at the corner of the road with Nutfield Lane, where the Folkestone Sands are again exposed, and at one place capped by a greenish-sand containing numerous phosphatic nodules, which may belong either to the top of the Folkestone Beds or to the base of the Gault in an exceptionally sandy condition. In another part of this same pit the Folkestone Beds are covered by a greyish Drift sand containing a few flint pebbles.

The party then proceeded northward, on the embankment of the new railway from Croydon to Redhill, to the escarpment of the Upper Greensand on the east of Merstham Church, where a deep cutting is now being made through the upper beds of the Gault and the Upper Greensand. The Gault is here a calcareous sandy clay in which numerous Foraminifera and Entomostraca can be seen with a lens, and overlying this the harder and more sandy beds of the Upper Greensand appear without any definite

plane of division. These latter are succeeded by the grey siliceous beds of stone which were formerly largely quarried for building. It was pointed out that the peculiar character of these so-called malm, firestone, or hearthstone beds was due to the fact that they largely consisted of sponge-spicules, the silica of which remained in an opalised or amorphous condition. The stone beds are succeeded above by layers of greenish glauconitic sand which are exposed at the northern end of the present cutting.

In a field a short distance to the east of the cutting a small quarry was visited, in which the mode of working the building-stone of the Upper Greensand by short tunnels could be seen.

From this quarry a short footpath led to the extensive Chalk Pits, where the beds of the Lower Chalk are largely worked for making lime. The different character of the beds of the massive and harder Middle Chalk from those of the thinner-bedded marly Lower Chalk were pointed out by Mr. Whitaker in the face of the quarry, but the position of the Melbourn Rock was for the most part hidden by talus.

On the way back to Merstham a visit was paid to the Church, and the excursion was brought to a close by tea at the Feathers Inn, and the 7.55 train was then taken for London.

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 1875. W. TOPLEY.—“The Geology of the Weald.” *Mem. Geol. Survey*.
 1887. ———.—“Excursion to Merstham, Redhill, and Reigate.” *Proc. Geol. Assoc.*, vol. x, p. 154.

ORDINARY MEETING.

FRIDAY, JUNE 4TH, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

The following was elected a member of the Association:
 John Sheer.

Miss Macmillan Scott and Miss Monk were nominated for membership.

The PRESIDENT exhibited, on behalf of Mr. McNeill, some beautiful enlargements of photographs taken during the Dover Excursion.

Mr. OSBORNE WHITE read a paper “On the Origin of the High Level Gravels with Triassic *débris* adjoining the Valley of the Upper Thames,” and illustrated his remarks with maps and specimens.

JULY, 1897.]

ORDINARY MEETING.

FRIDAY, JULY 2ND, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected members of the Association: Miss Macmillan Scott and Miss Ellen S. Monk.

Frederick Douglass, B.Sc., was nominated for membership.

The PRESIDENT called attention to the loss the Association was about to suffer owing to the retirement of the Secretary, Mr. C. D. Sherborn, who for the past eight years fulfilled the duties of his office in a most efficient and able manner. The flourishing condition of the Association was evidence of the skill and tact of its Honorary Secretary.

The Council and members much regret that Mr. Sherborn has found it necessary to take this step, and, whilst accepting his resignation, desire to record their sincere appreciation of his services, and to offer him their warmest thanks for the time and trouble he has so freely bestowed upon the Association.

The PRESIDENT exhibited, on behalf of Mr. Kenneth Pearl from the Coralline Crag.

The following papers were read with reference to the Excursion :

"An Outline of the Geological History of the Rocks around Edinburgh" by J. G. GOODCHILD, H.M. Geol. Survey.

"On the Excursions from Bathgate to Linlithgow, and from Linlithgow to Elie," by Prof. JAMES GRIKIE, LL.D., F.R.S.

"Fish Remains in the Abden Bone-bed," by R. I. M.D., F.R.S.

"On the Stirling District," by H. W. MONCKTON, F.L.S.,

Mr. GOODCHILD explained the geology of the Stirling District (including the subject-matter of the Paper) and illustrated his remarks by the lantern.

The SECRETARY announced that the books forming the Library of the Association had been removed from the St. Martin Free Library, and were available for reference by the Members of the Association. When further arrangements have been made due notice will be given on the Council. *Until that notice appears no book can be borrowed from the St. Martin Free Library.*

JULY, 1897.]

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FRIDAY, JULY 2ND, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected members of the Association: Miss Macmillan Scott and Miss Ellen S. Monk.

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The Council and members much regret that Mr. Sherborn has found it necessary to take this step, and, whilst reluctantly accepting his resignation, desire to record their sincere appreciation of his services, and to offer him their warmest thanks for the time and trouble he has so freely bestowed upon the affairs of the Association.

The PRESIDENT exhibited, on behalf of Mr. Kennard, a Fossil Pearl from the Coralline Crag.

The following papers were read with reference to the Long Excursion :

"An Outline of the Geological History of the Rocks around Edinburgh," by J. G. GOODCHILD, H.M. Geol. Survey.

"On the Excursions from Bathgate to Linlithgow, and from St. Monans to Elie," by Prof. JAMES GRIKIE, LL.D., F.R.S.

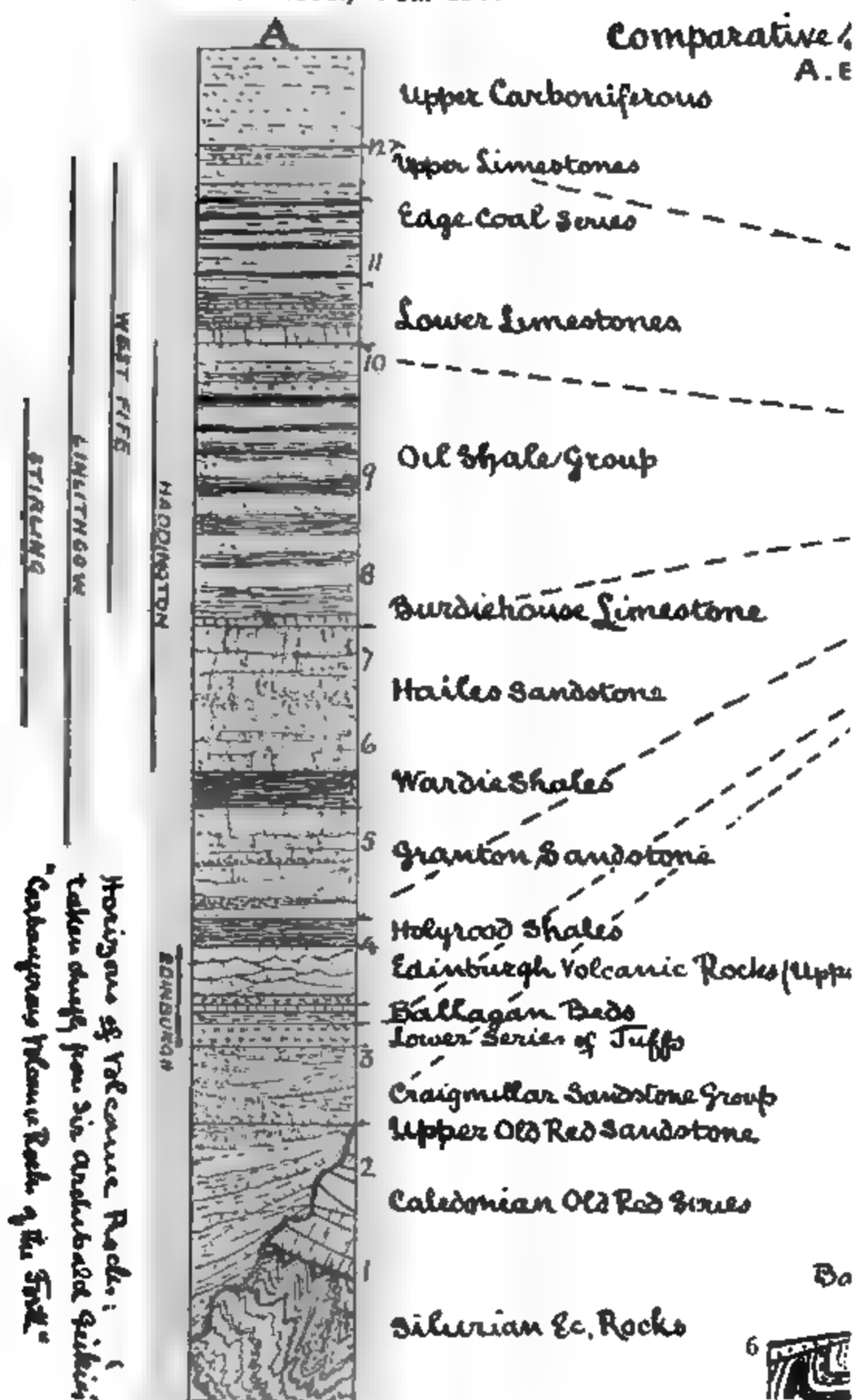
"Fish Remains in the Abden Bone-bed," by R. H. TRAQUAIR, M.D., F.R.S.

"On the Stirling District," by H. W. MONCKTON, F.L.S., F.G.S.

Mr. GOODCHILD explained the geology of the Edinburgh District (including the subject-matter of the Papers), and illustrated his remarks by the lantern.

The SECRETARY announced that the bulk of the books forming the Library of the Association had been removed to St. Martin Free Library, and were available for *reference only* to the Members of the Association. When further arrangements have been made due notice will be given on the Circulars; *but until that notice appears no book can be borrowed from the St. Martin Free Library.*

JULY, 1897.]



OUTLINE OF THE GEOLOGICAL HISTORY OF THE ROCKS AROUND EDINBURGH.

GOODCHILD, H.M. Geol. Survey, F.G.S., F.Z.S., M.B.O.U., Curator of the
Section of Scottish Geology and Mineralogy in the Edinburgh Museum of Science
and Art.

July 2nd, 1897. *Communicated by permission of the Director-General of the
Geological Survey.*

INTRODUCTION.

The geological structure of the district of which Edinburgh is the centre is so complex, and the evidence available for study is of so disconnected a character, that it is hardly possible, even with the aid of good maps and guides, to study all essential features in less time than twenty whole days. One may, it is true, visit and carefully examine part of the field in less time than that; but to attempt to gain any insight into the geological structure of the district as a whole in less time than that named would be to leave unseen evidence of a kind that cannot well be gathered from maps or books. Without a proper understanding of much of the evidence in the field, the geologist simply has to take what from others, statements which it is of much importance he should test on the ground for himself, if his visit is to be of real use.

In writing the outline which follows, I have borne this difficulty constantly in mind, and have endeavoured to plan such a series of excursions as may, when completed, form a consecutive series, which will enable the geologist who studies the evidence on the ground, with the Geological Survey Maps in hand, to gain a comprehensive view of at least the broader features of each locality visited, and to pass from the consideration of the oldest part of the geological record extant around Edinburgh by step to that of successively-later chapters of its history as the commencement of Upper Carboniferous times. In the concluding note some features of interest in connection with later records of the district have received attention. To many of the larger details within these outlines the Geologists' Station will need to come again.

I have accordingly arranged to study (1) in the PENTLAND Hills, the Lower or Caledonian Old Red Volcanic Rocks, and their relation to the Silurian rocks below and to the Carboniferous rocks above. [AUGUST, 1897.]

rocks above; then (2) at Copeth* (SICCAR POINT), the relation of the Upper Old Red Sandstone to the rocks older in the series (here the Gala terrene of the Silurians); next (3) to study the older part of the Lower Carboniferous strata and their associated volcanic rocks in and around ARTHUR'S SEAT; then (4) to take up the history of the Lower Carboniferous rocks at Burntisland and carry it on by studying the fine sections exposed between KINGORN and KIRKCALDY, until we arrive within sight of the base of the Upper Carboniferous rocks at the town last named.

Beyond that, part of the later history will be taken up by Professor Geikie at ST. MONANS and ELIE.

Finally we shall study (5) some further part of the later history of the district by the aid of what can be seen at the BLACKFORD and BRAID HILLS.

Owing to tides, and other circumstances, these excursions cannot well be arranged in the consecutive order here given; but this will not materially affect the general plan.

The Comparative Table of Lower Carboniferous Rocks (Pl. VI) appended to this will serve to explain much referred to in the text.

I.—PENTLAND EXCURSION.

Leaving the Caledonian Station by train for Balerno, we enter upon the part of the Lower Carboniferous rocks in which are situated the Sandstones of Hailes, Redhall, and Craigleith, and their associated shales of Wardie, etc., and we continue along their strike nearly the whole distance. The route lies most of the way amongst the picturesque scenery of the Water of Leith. On our right as we go lie strata which, on the whole, are somewhat higher in the Lower Carboniferous series; on our left successively-lower beds, also of Lower Carboniferous age, rise with the dip, or are faulted up to the surface, so that lower and older beds form the rising ground in that direction. With the uprise of the Carboniferous strata the base is eventually brought to the surface, and there emerges from beneath that base the *massif* of older rocks which once formed the floor upon which the Carboniferous rocks lay, but which, owing to its having been bent into an anticlinal fold from which the Carboniferous rocks have been subsequently denuded, is now left as the hard core of that anticlinal, which has been carved by rain and rivers into picturesque moun-

* Generally spelled "Cockburnspath"; the termination *pet* occurs in Morpeth, Elspeth, Brancepeth: in Pethhead, Peth o' Condry, and others. It is said to be Celtic, and to mean "a grassy flat at the foot of a steep bank."

POSTSCRIPT.—Since the foregoing notes were written Sir Archibald Geikie's *Ancient Volcanoes of Great Britain* has appeared. I have not yet had time to read it through, but I have already seen enough of it to warrant me in warmly recommending its study to all those who really desire to understand this most fascinating branch of geology; and especially to those who wish to learn all that is known regarding the volcanic rocks around Edinburgh.—J. G. G., May 20th, 1897.

tains and valleys. In brief, this may be regarded as the history of the Pentlands as a mountain-chain.

With the history of the Carboniferous rocks there, we have on this occasion but little concern; it will suffice to repeat that, as we ascend the slopes leading to the Pentlands from Balerno Station, we pass over the edges of successively-lower strata, until at Bavelaw Castle we come down upon the Upper Old Red, and, not much farther on, we meet with highly-inclined rocks of Silurian age, upon whose upturned edges the Upper Old Red here, as at the Siccar Point, lies with a violent unconformity. The Silurian rocks referred to are part of the mass of highly-plicated greywackes and argillites of Wenlock to Ludlow age, whose denuded edges constitute the floor upon which the chief masses of the Pentlands were laid down. These have the S.E. strike which characterises all the Pre-Devonian rocks in the south of Scotland. In the quarries and the natural sections to be visited by the Association a few fossils are to be found by carefully searching the rocks. These organic remains are chiefly small mollusca and brachiopoda, with a few monoprionidian graptolites, such as *Monograptus priodon*, *M. colonus*, *M. vomerinus*, and *Retiolites*. The chief Pentland localities for fossils are, however, some distance off, and could not well be visited by the Association on the present occasion.

Upon the upturned ends of these Silurian rocks (and also in places upon the upturned ends of the sandstones which are generally classed with the Lower Old Red) lies, with a violent unconformity, the Old Red Series (Caledonian Old Red, *mihi*) of the Pentlands. Where these rocks are most fully developed they consist of a considerable thickness of basal conglomerates (very probably filling up old valleys, and representing the torrential débris of this part of the Devonian period here), which conglomerates are succeeded by fully 6,000 feet of lavas and tuffs, with some few bands of sandstone.* The whole series was almost certainly laid down under continental conditions, while sub-arid meteorological conditions prevailed. Their relations to the overlying Upper Old Red, and to the Silurians as well as to both the Lower Old Red Sandstones, are shown diagrammatically on the plate of sections accompanying this.

The conglomerates, as might be expected to be the case under these circumstances, are of very local occurrence; so that in places they are entirely absent, and the lavas repose directly upon the floor formed by the edges of the Silurian Rocks. This is the case close to Bavelaw Castle. The conglomerates (here, as elsewhere) are full of interest, if only on account of their containing a most varied assortment of rocks derived from the Lower and Upper Silurian, etc., rocks of the Southern Uplands. They are seen in

* Sir Archibald Geikie (*Ancient Volcanoes of Great Britain*) gives a most valuable summary of what is known regarding the rocks of Devonian age of the Pentlands, etc.

Logan Burn and Monksburn, and they include in these places many blocks of the Arenig Radiolarian Chert, now altered into jasper; also blocks of the Haggis Rock, a conglomerate of Bala age; and a host of other rocks as well. In addition to these, this Pentland conglomerate has long been celebrated for containing blocks of a fossiliferous limestone, which has hitherto not been satisfactorily traced to its parent source. Mr. Peach thinks it may be one of the Silurian limestones, which locally occur at no great distance. Its fossils, however, appear to many persons to possess a different facies from those of the Silurian rocks.

During the building up of the volcanic rocks which now form the Pentlands, it must often have happened, especially towards the close of the period when the volcanoes had reached a great size, that the superincumbent pressure upon the molten rock rising in the direction of the surface was too great for the subterranean impelling agent to overcome. Under those circumstances, much of the rock that would have taken on the form of a lava flow, if it had risen to the surface, was forced in amongst the strata underground. In some parts it would invade the Silurian rocks, in others the overlying conglomerates, and in yet other localities the lavas and tuffs. One such mass, of considerable size, and producing contact phenomena of considerable interest, will be passed on the way across the hills. This is the rock of Black Hill, which, by the way, may *really* be of the nature of a laccolite—that is to say, it may have been intruded under such conditions of temperature, fluidity of the mass, and superincumbent pressure, as to allow of the molten mass actually *lifting* the overlying strata, as laccolites are shown to do in text-books, and as intrusive masses are almost never found to do in the field. But there is no clear proof that it is so, even in this case.

The volcanic rocks consist chiefly of lavas, the tuffs being thin and relatively unimportant. The lavas, lithologically considered, are somewhat more varied than is usually the case. Generally the Old Red lavas consist of but little else than one or other of the many forms of Andesite; but these of the Pentlands range almost from basalts, or at least from basalt-andesites, through andesites of various kinds, to trachytes, or even more acid lavas than these. The lowest lavas are andesitic, then come more acid rocks, next a second andesite group, followed by a second more acid series, and terminated, so far as the present section is concerned, by andesite once again. A few necks, representing the cores of parasitic cones, occur here and there, but are not seen along the line between Balerno and Penicuik. It will be seen by the Survey Map that the rocks of the Braid Hills have been mapped as part of a great neck. Some of the tuffs show interesting examples of raindrops, which, in descending through an atmosphere charged with fine volcanic dust, have caught up much of this and have reached the earth as globules of ashy mud.

Dr. Johnston Lavis appears to have been the first to recognise these. A good example is seen in a quarry between Scald Law and Carnethy.

After the volcano ceased to erupt, the whole area underwent some disturbance and considerable denudation, and then the Upper Old Red was eventually deposited, still under continental conditions, upon the very irregular surface formed by the older rocks. After that came a change of climate from arid to humid, perhaps as a consequence of the descent of the land. During this subsidence the Carboniferous rocks, twelve or more thousands of feet in thickness, were deposited over the entire area now occupied by the Pentlands.

Of its later history there is no need to state much here. Valleys were carved into the *massif* long prior to the Glacial Period. During that time land ice flowed from the mountains lying to the north-west of the Forth basin, thence up the Clyde, over the watershed of that river into the basin of the Forth, and then over all the hills of the Lowlands out to what is now the North Sea. The very highest summits, as well as the slopes, of the Pentlands, are marked with the characteristic grooves and striæ left by the ice; and the boulder-clay, which represents the mud and sediment carried upward and forward in the ice sheet, now forms the till, and is the source of the many far-derived boulders for which the Pentland area has long been famous. Some boulders of mica schist from near Loch Lomond lie close to the path from Balerno to Penicuik, and can easily be inspected. One of these near Loganlee has been much visited and often described. It weighs several tons.

One or two small moraines of the later glaciers occur in this neighbourhood; but the most striking example is to be found nearer the southern end of the Pentlands, in the neighbourhood of West Linton and Slipperfield, where a fine crescentic group of moraines of large size lies off the mouth of one of the larger valleys. I am not aware that its nature has been previously noticed.

Just before leaving the Pentlands properly so called, the party will have an excellent opportunity of obtaining good specimens of the so-called "porphyrite" of Carnethy, which is an andesite lava containing large tabular crystals of twinned labradorite. Agates occur in this, as does also mineral bitumen, together with small crystals of cairngorm.

The Pentlands are bounded on the east side by a large fault, which lets down the Lower Carboniferous rocks near to the hills. These dip towards the low ground at a high angle, and are stained by infiltration from the New Red rocks which have lately disappeared, so that Upper Carboniferous rocks, bright red in many cases, occur there to a considerable thickness, and were at one time regarded as Permian.

Close to the boundary fault occurs a small group of eskers, which, as the present writer first suggested in 1874,* represent the stony materials which were liberated from the interior of the ice sheet on to its surface as it melted, and were afterwards washed down into the gradually-widening crevasses.

II—SICCAR POINT AND "COCKBURNSPATH" OR COPETH.

On the arrival of the train at "Cockburnspath" (or Copeth, as it is locally and more commonly called), the party will walk along the road in the direction of Berwick. Part of the way the journey will lie over the sandstones at the base of the Lower Carboniferous Rocks, and then for a short distance over the Upper Old Red Sandstone. At Peaseburn a fine example of a dene eroded in these rocks will be examined. The Old Red here consists of the usual alternations of red sandstone and conglomerate, which dip in a northerly direction or, on the whole, down the burn. The dene is a typical example of a smaller valley, more or less in the form of a cañon, lying within a larger valley whose sides slope at a much lower angle. Its history appears to be that the larger valley was shaped by sub-aerial causes by the ancestor of the present burn before the Glacial Period, when the land stood at a much higher level, and when what is now the North Sea was then simply the valley of the Rhine. During the Glacial Period the old valley was modified by glacial action, one of the results being the formation of a series of grooves of glacial origin, which, as Sir Archibald Geikie pointed out in the *Geol. Survey Memoir* on the Geology of the Berwick Coast, here furrow the surface of the rocks in a south-easterly direction. Near the close of the Glacial Period the land had subsided to considerably below its present level. On the disappearance of the ice, the water of the North Sea gained admittance to this part, perhaps for the first time, and some of the higher-lying marine terraces were formed, of which conspicuous examples do not happen to occur in this immediate neighbourhood. Under these conditions the flow of the Peaseburn at this point must have been reduced to its lowest possible rate, with, as a consequence, a minimum amount of vertical erosion compared with the lateral. Then the land rose in a succession of starts, with long pauses between each. At every uprise the rate of flow of the stream at a point close to the sea must necessarily have been increased in proportion to the gradient so formed, and the vertical eroding power of the burn was therefore increased in relation to the rate of lateral erosion. Patches of the old alluvium

* *Geol. Mag.*, Nov., 1874, "On Drift."

found when the land stood at a much lower level above the sea remain on the edges of some of these denes fifty or sixty feet above the present level of the stream.

Leaving Pease Bridge the party will next walk in the direction of the quarries at Old Cambus. Here the rocks consist of close alternations of beds of greywacke and argillite, this latter being occasionally affected by cleavage, and therefore becoming a slate. The rocks in question belong to the Gala Group, equivalent to the Welsh Tarannon subdivision of the Silurian, and the equivalent in time also of the Pale Slates of the English Lake District. As might be expected, considering their mineral composition, they are very much thicker than their deep-water equivalents in the Lake District. They have been subjected to intense compression, which has thrown them into a series of complex folds whose axes range in a general N.E. and S.W. direction. Professor Lapworth pointed out many years ago that it is rocks mainly of this age, repeated by innumerable closely-pressed and often inverted folds, which constitute fully one-third of the superficial area of the Scottish Southern Uplands. It is almost entirely out of these convoluted greywackes and argillites that the Lammermuirs and Moorfoot Hills have been shaped. It is these, also, which form the striking range of cliffs of greater part of the Berwickshire coast. Figures showing the remarkably convoluted character of these rocks are given in the Survey Memoir by Sir Archibald Geikie on Sheet 34, Scotland.

It can easily be shown that the disturbances to which these convolutions are due commenced at a period late in the history of the Silurian rocks themselves, and were continued, contemporaneously with denudation to a prodigious extent—many thousands of feet of rock having been removed in the process—until the rocks were planed down to near the geological horizons out of which much of the present surface is shaped. Upon the upturned and denuded edges of these were afterwards laid down the great group of volcanic rocks whose remnants constitute the Cheviots, and many of the patches of eruptive rocks seen along the coast from a little north of Berwick to St. Abb's Head.

Long after volcanic action ceased arid or perhaps even desert conditions set in here, and it was under these conditions, while the land stood at a much higher level, that the Upper Old Red Sandstone was formed. This consists partly of torrential deposits, chiefly accumulated in old wadys, strata formed in inland lakes, and wind-blown sands. Then came a gradual change from arid to humid conditions, accompanying—and probably a consequence of—the long-continued subsidence under which the Carboniferous rocks were formed. After a long series of other changes the newer rocks were in their turn removed and the present surface features left.

The party will spend about one hour at Old Cambus Quarry, where typical examples of the fossils characteristic of the Gala Group, or of rocks in general of Tarannon age, may be found. Here, on Easter Monday of 1897, the present writer's students obtained ten species of graptolites. These were identified by Mr. Macconochie as: *Monograptus priodon*, *M. pandus*, *M. vomerinus*, *M. exiguus*, *M. turriculatus*, *M. convolutus*, *M. hisingeri*, *M. crispus*, *M. leptotheca*, and *Diplograptus sinuatus*; together with many good examples of "annelid" tracks.

After leaving Old Cambus Quarry the party will traverse one of the remarkable south-easterly grooves above referred to as occurring so commonly along this part of Berwickshire. Like the easterly grooves of the Lothians, these Berwickshire grooves coincide in direction with the glacial markings, and with the general direction of transport of the far-travelled boulders. I do not hesitate to regard the furrows in question as the work of land ice during the Glacial Period, as was originally suggested thirty-four years ago by Sir Archibald Geikie.*

After a walk of a few hundred yards along the furrow just mentioned, the party will climb its eastern bank, and in the course of a few minutes' walk will find themselves at the edge of a cliff of thinly bedded bright-red sandstone. This is the Upper Old Red. It is somewhat disturbed and faulted. It yields scales of *Holoptychius* along one of the bands, which band, though easily seen, there will not be time to visit. Going northwards along the edge of the cliff about a hundred yards or so, we come upon a steep grassy bank leading down to the foot of the cliff. Taking due precautions in the descent, we soon find ourselves face to face with the celebrated unconformable junction of the Upper Old Red Conglomerate and the Silurian (Tarannon) rocks, first recognised by Hutton. These latter are almost exactly vertical, and strike at right angles to the coast, while the Old Red lies with a very gentle inclination upon the edges of the older rocks, and strikes in a general way nearly parallel to the coast. It will be observed that the plane of junction between the two formations is a somewhat uneven one, as indeed is usually the case with strata formed under continental conditions, especially when these coincide with an area of small rainfall. As other examples of strata so formed, the New Red and the Torridonians may be mentioned. The conglomerate is of course made up largely, though not exclusively, of the finer torrential matter transported from the areas of older palæozoic rocks. It contains in addition to these constituents some stones from the older Old Red which formerly covered these parts, and also some few others whose origin cannot be traced with certainty.

It may be of interest to reflect upon the time represented by

* *Op. cit.*, p. 52.

this grand example of an unconformity. According to the computation made by the writer, the changes that took place **a**fter the formation of the Gala or Tarannon Rocks at the Siccar **P**oint and before the commencement of the period when the **U**pper Old Red was formed, require for their accomplishment **1** 50,000,000 years.*

Returning to the edge of the cliff, the party will walk northward along the strike of the Old Red for about a quarter of a mile, beyond which they will again descend to the beach, for the purpose of studying the petrographical characters of the Upper Old Red, of which rock at one point a considerable thickness will be traversed. The beds above the basement conglomerate consist of alternations of sandstones and flags, showing much strongly marked false-bedding, such as occurs in desert sandhills, together with beds of red marl, which probably represent deposits formed in the "schotts" of the period. Poikilitic mottling is remarkably well seen in many places. Much of the sandstone consists of well-rounded grains of quartz, etc., in no way distinguishable, except in colour, from the desert sands of Egypt of the present day. Much secondary quartz is deposited upon the faces of the cleaner of these grains, and very beautiful examples can easily be obtained.

After a rough scramble over the fallen blocks for a distance of a few hundred yards, we find ourselves, as we go northward, crossing the edges of sandstones and marls in which the ferric oxide colouration gradually disappears, and in which more or less calcareous concretionary masses begin to make their appearance in the sandstone. These evidently mark the incoming of more humid conditions and the gradual increase in organic matter swept into the waters. By degrees, as the succession is followed northward and upward, plant- and animal-remains begin to occur in the rocks, the sandstones no longer consist of rounded grains of sand and are no longer red or mottled, and we are at the base of the Carboniferous rocks.

If time permit, these Carboniferous rocks may be followed as far as Cove; otherwise the ascent will be made sooner.

III.—ARTHUR'S SEAT.

The earlier chapters of the geological history of Arthur's Seat bring before us a record of an old land surface, probably formed mainly of rocks belonging to the Caledonian Old Red, but partly also shaped out of the ends of highly contorted Silurian and other rocks of still older date. There is good reason for believing

* Goodchild, "Age of the Earth," *Proc. Royal Physical Society* (1897), vol. xiii, pp. 259-308.

that the land surface in question was one presenting much irregularity of form; but whether any of the eminences formed of these older rocks which exist as elevated areas now were such then, is by no means certain in all cases. The Upper Old Red Sandstone which was deposited upon this surface certainly contains records of a period when arid conditions prevailed here; for whatever rain fell, came at intervals too irregular to permit of the growth of vegetation. Hence, where the form of the ground was such as to permit of the existence of lakes, the quantity of organic matter swept into those lakes was usually too small to reduce the iron salts carried in solution into them. Consequently these iron salts were usually left, coating the sand grains as ferric oxide.*

Under these arid conditions was formed a series of deposits which, in some places, were simply accumulations of wind-blown sands, in others torrential deposits filling up the old wadys, in yet others deposits formed in old "schotts," like those of Algeria. Hence the distribution of the Upper Old Red, here as elsewhere, is one of great irregularity; and there are necessarily many areas where no deposits of any kind belonging to this period were left.

Rocks formed in this way constitute the surface strata all over the southern part of Edinburgh.

Towards the close of the period subsidences of a local nature commenced, and were continued for some time. One important result of the change was the introduction of meteorological conditions of a different order from what had prevailed before. Rain fell with more regularity, the quantity of aqueous vapour in the atmosphere considerably reduced the diurnal range of temperature, and rock-weathering of the normal type again prevailed. With the return of humid conditions vegetation flourished, and animal life began to abound.

It was under these conditions that the rocks occurring in the northern part of the Old Town of Edinburgh and the western parts of the Queen's Park were formed. The sea had not yet gained a permanent entry; but the area probably formed part of a lagoon, or consisted, perhaps, of a series of lagoons, liable to alternate flooding and desiccation; the rate of deposition of rock material brought in by the old river, whose course here lay south-eastward, being generally balanced by the rate of subsidence. During the periods of drought concentration of the salts brought down by the river went on, and we accordingly find temporary records of an occasional return to conditions similar to those under which the Upper Old Red was formed. Sun cracks, rain prints, shale galls, pseudomorphs of rock-salt, variegated sandstones and marls—here reddish, there green—are found alternately with sandstones and shales of the normal colour. But owing to the frequent presence of organic matter in the river water, ferric

* See Hudleston, *Proc. Geol. Assoc.*, vol. xi, p. 104.

oxide was precipitated much less frequently than before. The **same** cause also gave rise to another effect of some interest and **importance**. The river brought down lime-salts in solution, probably sulphate of lime amongst the others. The joint action of **desiccation** and the presence of organic matter gave rise to the **precipitation** of much of this. Generally the precipitated **carbonate** of lime took the form of nodular concretions, or **con-stones**; but in many cases here it would seem to have been **deposited** in the form of thin crusts. These irregular sheets of **chemically-formed carbonate** of lime were generally broken up, **and** their fragments drifted seawards each time a flood came, **and** were thus mingled with the older derivative material being swept **forward** by the currents.

Under some such conditions as these were the rocks formed **which** now constitute the dip slopes on the west side of Hunter's **Bog**, and most of the steep scarp extending downward from **Salisbury Crag** to the Queen's Drive below; they are also well **seen** on the south-east side of the Edinburgh Castle Rock and at **Craigmillar**, from which locality they are named.

These strata exactly correspond in petrographical character **and** in stratigraphical position to the rocks called the Lower Lime-**stone** Shale on the English side of the Border.

Then followed a more rapid subsidence, during which the sea **may** frequently have gained admission, although the general absence **of** organic remains forbids us to speak with absolute confidence **upon** this point. Under these conditions was formed a mass of **shales** and cement stones, with occasional bands of sandstone, **and** some few bands of limestone of a peculiar type. The rocks **referred** to are the Ballagan Beds of Glasgow geologists. They **are** probably the same as the Cement Stone Series of the Border **counties** and the lower part of the Roman Fell Series (and therefore of the Mountain Limestone) of Westmoreland, as is shown in the comparative sections appended to this.

While these rocks were in process of formation here a volcano, **or**, perhaps, a series of volcanoes, arose in some part of the area **to** the west of the area specially under notice. (Many geologists, **looking** westward from the present Arthur's Seat, have been led **to** speculate whether the Edinburgh Castle Rock might not mark **the** site of the volcano in question; but upon this point there is **at** present not much agreement amongst them.) The precise **nature** of its earliest eruptions must always remain unknown; **but** we do know that while the Ballagan Beds were being **deposited** in the area now represented by the Queen's Park and **the** Calton Hill the volcano did now and then, early in its **developmental** history, give rise to explosive eruptions, which **occasionally** were of a sufficiently violent nature to project more **or** less fragmentary eruptive material to such a distance as to **fall** within one part or another of the areas under notice. Hence

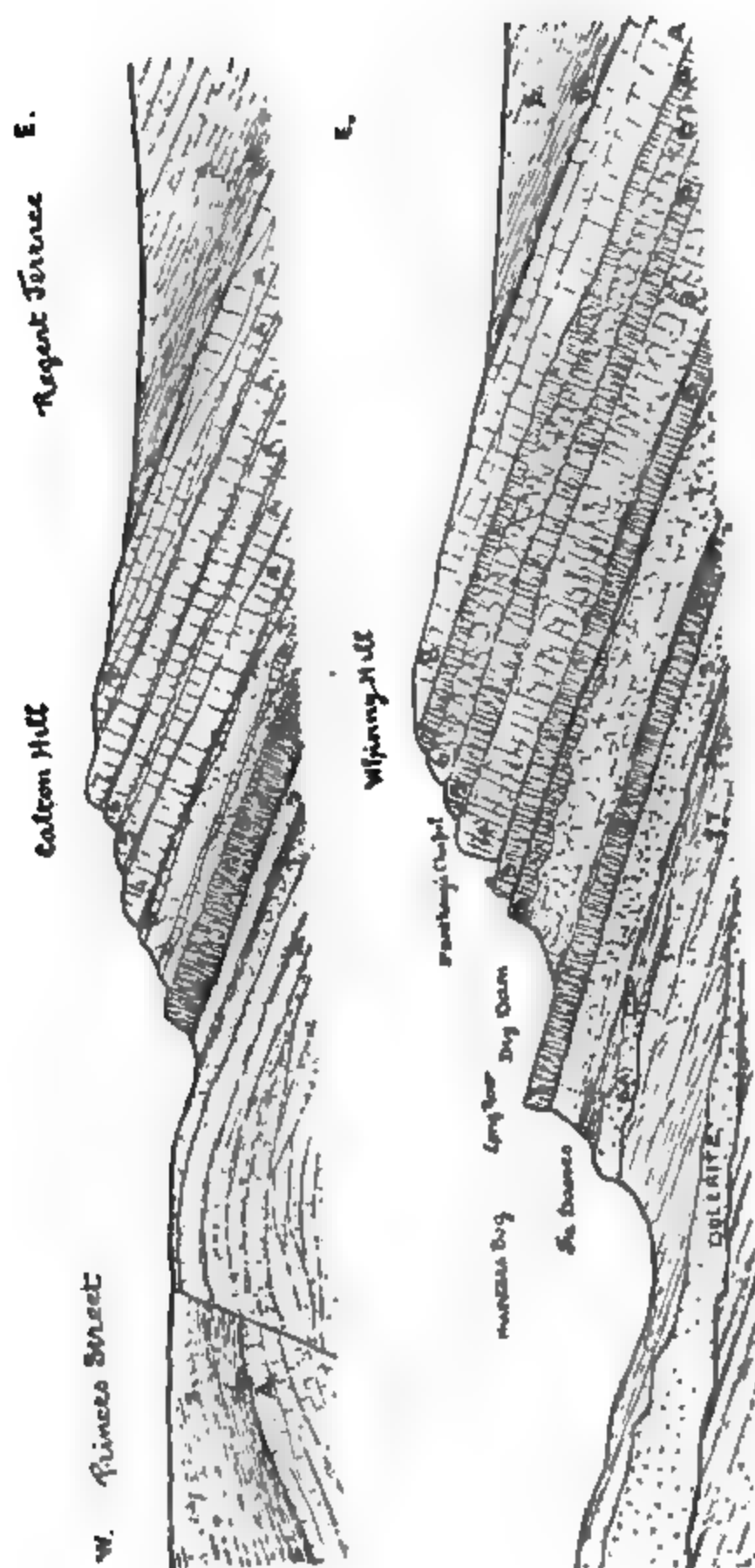


FIG 1.—Diagram Sections across the Carlton Hill and the Northern End of Andrew's Gate
 1. Carlton Hill and exposed from 29 119

it happened that the Ballagan Shales came to be interstratified with bands of tuff. Rocks formed during this period now form the lower part of Hunter's Bog, and much of the rising ground to the east of that depression. They occur also along the High Street and the Canongate of Edinburgh, and were lately passed through in the Abbey Hill Bore, No. 2, cores from which are exhibited in the Edinburgh Museum of Science and Art.

Concurrently with the upgrowth of the volcano there arose hot springs, and perhaps also geysers. From these were deposited beds of calcareous and siliceous sinter, which were spread out in thin layers in the vicinity of their orifices. During the earthquakes that accompanied the growth of the volcano these beds of sinter underwent many crumplings and occasional fractures, after each of which events quiet deposition went on as before. Several deposits of this kind occur in connection with the old Edinburgh Volcano, and may be seen at various places in the Queen's Park.

Then came a succession of periods of more violent explosive eruption, alternately with conditions favourable for the growth of beds of sandstone. This rock was seen at the Waverley Station, and below the Waterloo Bridge, and was also passed through in the borehole No. 2 at Abbey Hill, above referred to (see also *Trans. Geol. Soc.*, Edin., 1897, p.).* These were followed by the outpouring of one or more beds of basalt lava, while the area was still submerged. One of these flowed in the direction of Arthur's Seat, and now forms the Long Row. Another may be represented by the lowest lava seen below the Calton Gaol. Then came a period of quiescence, during which another band of geyserite was formed. This is seen on the south side of the Queen's Park, between Windy Gowl and the Queen's Drive. A succession of explosive eruptions of a more or less violent character next took place. Then came a basalt lava flow, which was heavily charged with H_2O , and is in consequence now full of vapour cavities, some of which have been at one time filled with amygdules of calcite. This flowed in the direction of the Queen's Park only, as it is not represented on the Calton Hill.

Submergence still continued, and perhaps kept pace with the growth of the volcano, for we find that the beds overlying the last-mentioned lava consist of stratified tuff, in which remains of *Rhizodus* and transported fragments of *Lepidodendron* occur. In these beds, which are, as a rule, fine-grained, and of only a few feet in thickness, there occur large ejected blocks, one of which, seen just below St. Anthnoy's Chapel, may really be a volcanic bomb, which, it may be mentioned here, is a geological phenomenon of by no means common occurrence, notwithstanding what has often been stated to the contrary. This thin bed of tuff is succeeded on Arthur's Seat by a compact basalt

* This paper is not yet paged, September 11th, 1897.

lava, very columnar in structure, showing traces of fluxion structure on its weathered surface and weathering a bright rust-red colour. This is No. 3 Lava. No lava of basaltic composition occurs on the Calton Hill above the bed at the base of the series, the higher beds there being exclusively andesites. From this consideration, and others of a similar nature, we may infer that the present outcrop of the older lavas on Arthur's Seat does not coincide with the original longer dimensions of the lava streams, but rather with their breadth, those on the Calton Hill representing streams from other vents.

Another bed of geyserite, accompanied by a thin band of tuff, succeeds the red lava (No. 3), and is followed by a remarkably brecciated lava (No. 4). Probably the portion of the rock exposed, which is best seen in the cliff-face due east of St. Anthony's Chapel, may be near the original termination of this lava stream, which, as is well known in the case of recent lavas, is often both scoriaceous and brecciated in much the same manner as the one under notice.

Three other lava-flows poured from the Edinburgh Volcano in the direction of what is now the Queen's Park. Of these the older two were basalts, the lower of which even yet contains olivines in a fresh condition, and is remarkable for its bomboidal or pillowy structure. The higher lava, and last flow of this set to reach Arthur's Seat, is a true andesite, similar to those which form the mass of the Calton Hill volcanic rocks, and containing large tabular crystals of Labradorite. This is the rock which forms most of the eastern side of Arthur's Seat, and which both caps and forms the east slope of Dunsappie.

Contemporaneously with the eruption of these lavas and tuffs there was intruded underground three sheets or sills of rock. The lowest of these is a porphyritic basalt, which now forms the rock of St. Leonard's Crag and Heriot Mount. This rock occurs in the form of a wedge, with its base towards the west. It cuts across the strata from below upwards, as it is traced southward. The next is a typical dolerite, whose remains form a scarped edge, which presents a bold mural precipice facing to the westward, the well-known feature known as Salisbury Crag. Speaking in general terms, this rock also forms a wedge-shaped mass, thickest towards the west. It hardens the strata above it, but in the main it does not vary much from one geological horizon. Both of these may possibly represent underground intrusions of basic eruptive matter, which are possibly contemporaneous with the lavas of the same composition forming the main mass of the hill. The third intrusive mass is of a similar composition to that of the highest lava of the Queen's Park, and the bulk of the lavas of the Calton Hill, and is essentially an andesite. This rock forms a series of apparently discontinuous wedges, which are intruded into the Ballagan Beds on the east side of Hunter's Bog. It forms the

hills known as the Dasses. To these three intrusive masses **reference** will have again to be made.

The changes which followed the outpouring of the last-formed **of** the lavas on Arthur's Seat are not difficult to describe. The **newly-finished** volcano sank more rapidly than heretofore, and the **sea** for a time gained admittance. At the bottom of this was laid **down** a series of beds of marine shale, enclosing fossils; and **then** followed either a rapid silting up of the sea bottom or else **a** slight movement in an upward direction. At any rate, it is clear that the next strata formed (the Granton Sandstones of the General Section) were estuarine in character, and were formed throughout in shallow water. Then follows a record of a succession of marine conditions, marking the periods of more rapid subsidence, and of estuarine conditions when the water was shallower, and the old delta of the river, which was transporting the material from the north-west, effected more or less advance seaward. It is important to remember that the strata from the Ballagan Beds, up to the horizon under description, are undoubtedly equivalent in time to the Mountain Limestone of the North of England.

Next, in this area, followed the conditions which gave rise to the formation of lagoons, alternating with estuarine conditions, under which in this neighbourhood the Oil Shale Series was formed. This series is contemporaneous with the Scremerston Coals of Northumberland. It was also the chief period of Lower Carboniferous volcanic agency in the areas adjoining Edinburgh. Then came the period during which a very general subsidence took place, and when the limestones of the Yoredale Series were spread out continuously over so large an area of North Britain. The lowest limestone of this, the Hurlet, Main, or Gilmerton Limestone, is probably contemporaneous with the Middle Limestone of Phillips's typical Yoredale Sections, with the Scar Limestone of Cumberland, and with the Lamberton Limestone of the Berwickshire coast. It is as well to remind the reader that the limestone referred to overlies the Oil Shales, and their contemporaneous deposits the Scremerston Coals so important in Northumberland, and that it underlies the Edge Coal Series, also of Lower Carboniferous age, which are of so much importance in Fife and the Lothians.

Following the marine episode during which the Yoredale Rocks were formed, came the prolonged period of estuarine—possibly even, occasionally, fresh-water—conditions, under which much of the Upper Carboniferous rocks were formed. It will suffice here to state that the older volcanic rocks of Arthur's Seat were covered up by several thousand feet of Carboniferous strata, all of which has, of course, since been removed by denudation.

Then came a period of prolonged disturbance, during which

the first formed strata were much folded and faulted. This was followed by upheaval and denudation, and a return to continental conditions. It was under these conditions that the New Red Rocks (Dyas, Lower New Red, or Permian, plus the Trias) were formed. Sir Archibald Geikie described many years ago an interesting series of volcanic rocks which were formed in Ayrshire during this period, to which reference will again be made.

We must now, however, return to study some of the evidence relating to the later formed rocks on Arthur's Seat. The main facts may be set before the reader in a few words. It is abundantly clear from a study of the evidence on the ground that there are eruptive rocks belonging to *two* periods on Arthur's Seat. The rock of the Dasses, for example, and the rock of the Long Row, can both be followed southward without any interruption up to a certain point, where they both abruptly terminate against rocks of a totally different kind, which are easily seen to be those of which Arthur's Seat, properly so called, consists. If we go to the south side of the hill, and commence the examination at the west end of Duddingstone Loch, we find there also the rock of the Dasses and the rock of the Long Row. Both of these can easily be traced northward up to a certain distance, and at that point what are very obviously agglomerates filling an old volcanic neck truncate them abruptly, just as happens on the north side of the hill. (It seems, even to the writer, that facts of much the same nature can be made out with regard to both the dolerite of Salisbury Crags and the basalt of Heriot Mount.) No unprejudiced geologist could well have any doubt about the fact that he has before him in this case evidence of two sets of eruptions. Of the age of the one, whose products have already been described, there can be no doubt whatever. But regarding the age of the other—that which broke through the older set of lavas, etc., and filled the gap so formed by agglomerates and other such material—there has been considerable difference of opinion. Some have thought the newer rocks might be of Tertiary age. Others have thought that the whole set may be of Lower Carboniferous age, and may have come from the vent now represented by Arthur's Seat. Sir Archibald Geikie has maintained for many years the view that the newer vent may be of Permian age—a view which finds many supporters in Scotland. The evidence bearing upon this question is certainly very scanty, and, as Sir Archibald himself states, in his latest work, *The Ancient Volcanoes of Great Britain*, cannot be settled by exclusive reference to the facts presented by the hill itself, but must be studied in the light obtained from sources elsewhere.

Leaving this vexed question, we may now pass on to consider some of the later history of Arthur's Seat.

Soon after the close of the Carboniferous Period, the newly-formed rocks were thrown into a great and complex series of

elongated domes or ellipsoids, most of whose larger axes range in a general north-easterly direction, and whose steepest sides often face towards the east.

The axis of one of the great north-easterly upfolds coincided with the present physical axis of the Pentlands, which hills represent the harder core of one of the anticlinals re-exposed by the denudation of the softer strata which once folded over it. The axis of one of the main synclinals ranges parallel to this latter, and has helped to preserve the outlier of Upper Carboniferous forming the Dalkeith Coalfield from denudation. But so far as Arthur's Seat is concerned, we need only to have regard to the fact that the Pentland axis bends to the north as it ranges near Edinburgh, and then gives rise to a minor ellipsoidal area of up-folding, which traverses the site of Edinburgh along a northerly line ranging, in a general way, from the summits of the Braid and Blackford Hills to near to the Castle Rock, and thence onward in the direction of Leith Docks. To the east of this axis the strata, including those of Arthur's Seat and the Calton Hill, were made to dip north-easterly; while in the opposite direction they were inclined for some distance in a north-westerly direction. Arthur's Seat and the Calton Hill, it has to be remembered, once formed part of the east flank of the Edinburgh Volcano, of which they must be regarded as a segment accidentally preserved from the denudation which has removed most of the remainder, and were alike thrown, so to speak, on their side, when the strata of which they form a part underwent the north-easterly tilt referred to.

Then, some time after this folding took place, and while the old volcano still remained intact amidst its enveloping strata, a series of faults originated. These took a prevailing north-easterly direction. One very powerful one runs from Craiglockhart, along the west side of southern Edinburgh, to a point between the Castle Rock and Princes Street Station, and from there along the west side of the Calton Hill in the direction of Leith. This has thrown down a large section of the Edinburgh Volcano, which is accordingly beneath the surface of Princes Street. Another powerful fault, with a down-throw to the north, ranges between Holyrood and Arthur's Seat. Its effect, combined with that of the dip, has been to shift the outcrop of the Calton Hill section of the lava a mile to the west, and to bring down against strata three hundred or more feet below the base of the volcanic series, other marine strata which, on the Calton Hill and in both the Abbey Hill bore-holes, overlie the volcanic rocks. As the total thickness of these volcanic rocks has lately (1897) been proved, in the Abbey Hill bore-hole No. 2, to be 850 feet,* the throw of this fault cannot be less than a thousand feet, and may considerably exceed that amount. Another segment of the Edinburgh Volcano,

* In the Abbey Hill bore-hole two sets of volcanic rocks were proved, with a considerable thickness of sandstone and shales (part of the Ballagan Beds) between them.

consisting of basalts of a different type from those on Arthur's Seat, is left at Craiglockhart. These are described in detail in the *Ancient Volcanoes of Great Britain*.

There is some reason to believe that the present surface relief of the neighbourhood of Edinburgh is a "modified descendant" of that which the surface had at the commencement of "Permian" times, and which has been re-exposed by the removal of these and the overlying rocks of Neozoic age. The characteristic red-staining of the sandstones which happened to contain but little carbonaceous matter, and which have formerly been overlain by Red Rocks, is well seen at many places around Edinburgh, and, to my mind, puts this point beyond doubt.

As far as the shaping of the minor details of the surface is concerned, we have three factors to bear in mind. First, the result of prolonged exposure of rocks of very diverse powers of resistance to atmospheric waste, factors which in any case must have operated in such a fashion as to leave Arthur's Seat, the Calton Hill, the Castle Rock, and the Pentland Hills as upstanding masses. The minor work of sculpturing must have been largely ruled by the variations in destructibility of what we may term a lower grade; as, for example, the formation of terraces where sills of hard rock, such as lava, alternate with others consisting of tuff. The second factor is, of course, that of the streams, which may and do excavate their channels without always having their courses affected by the minor differences referred to.

The third factor is that arising from the prolonged glaciation, which not only very materially modified any pre-existing features it may have met with, but left marks peculiarly its own upon the rocks. The conjoined effects arising from these may be easily traced upon Arthur's Seat, and it is not difficult to point out which feature is due to the one cause and which to the other. The best place for the study of them as a whole, however, is at the north end of the Pentlands, between Allermuir and Swanston. At this locality there is first the great upstanding mass of the Pentlands, due to the removal of the outer and softer coatings of an old anticlinal, whose less easily-wasted core has in consequence been left in relief as an area of uplands. Next are easily seen the channels eroded on the slopes of this old core by the streams whose courses had been well-established in the strata that have since wasted away. Following these features in the order of magnitude are the escarpments and dip slopes arising from the inter-bedding of the lavas and tuffs, to which features Sir Archibald Geikie has so often made reference. Of lesser magnitude still is a series of deep grooves and ruts, which have been ploughed out of the edges of the escarpments by the passage over them of thick masses of land ice. Some of these grooves are of considerable magnitude; indeed on the Braid Hills, they would generally be

taken for river valleys but for their obvious parallelism, and for the fact that they tend to run into chains of rock basins. Lastly, and of least importance, are the roughenings of the once smooth and rounded crags, and the consequent formation of screes. Anyone whose eye has fully taken in the special characteristics of these several features, which are so well exhibited on the Pentland Hills, will have no difficulty in referring each grade of the surface-features on Arthur's Seat to the agency to which it was actually due. The beautiful corrie at the head of Dry Dam, and the numerous small rock basins which have been carved out of the lavas of Whinny Hill (Samson's Grave, for example), will be at once recognised by the trained eye as the work of ice. As for the fine examples of *roches moutonnées* and other glaciated surfaces, they will tell their own story, save only to those who obstinately turn a deaf ear to any such appeals to their reason.

Several minerals of interest occur in the hill. Not counting the rock-forming minerals we have: Quartz, and its amethystine modification, Chalcedony, Jasper, Agate, Chert in the geyserites, various forms of Calcite and of Pearlspar, Analcime, Prehnite, Natrolite, Celedonite, Glauconite, Hæmatite, Limonite, Goethite, Barytes, some Hydrocarbons (probably due to chemical changes affecting metallic carbides occurring in the neck, as I venture to think the DIAMOND also is), together with some few minerals of minor importance. Very fresh olivines occur in the *older* volcanic set, as well, of course, in the newer beds, such as that of the well-known Lion's Haunch.

IV.—BURNTISLAND, KINGORN, AND KIRKCALDY.

The rocks exposed along this part of the Firth of Forth continue the history of the Lower Carboniferous rocks from the geological horizon described in the section dealing with Arthur's Seat, and carry it on through the period represented by the Yoredale Rocks, properly so called, well into the lower part of the Upper Carboniferous.

As already mentioned, the Carboniferous rocks of the lower part of the Basin of the Forth were affected by powerful earth-movements at some period between the close of Carboniferous times and the commencement of the period represented by the New Red. Extensive denudation accompanied and followed these disturbances, so that the New Red and the succeeding Jurassic rocks were spread out upon an uneven floor, shaped out of a vast thickness of the older strata. One ellipsoidal area of upheaval has already been mentioned as ranging in at first a north-easterly direction through the Pentland, the Braid, and Blackford Hills; thence, in its trend northward, it passes through

Edinburgh and crosses the Forth, assuming, as it does so, first a north-westerly direction, and then bending round again to the north east, especially where the axis of the fold extends inland from Burntisland. Northward of this last town the fold gradually dies away. A synclinal, with a trend parallel to this, brings in, and has preserved from denudation, the Dalkeith Coalfield. This same down-fold crosses the Forth to the east of Inchkeith, and reaches the Fife coast to the east of Kirkcaldy, beyond which town this disturbance also gradually dies away.

At Burntisland (or a point a little to the west), therefore, we meet with the lowest strata exposed in this part of Fife; and from the axis passing through the part referred to the rocks are inclined with a fairly steady dip, amounting generally to about from ten degrees to twenty towards the east. In consequence of this high inclination of the strata, a thickness of Carboniferous rocks, amounting to several thousand feet, is brought down to the sea level within a zone a few miles in width. It happens in this area that the rocks are well-exposed in one part or another over nearly the whole of the coast, as well as in many fine sections inland. For this reason (and others to be presently mentioned) this part of the Fife coast has long been regarded as presenting one of the most important and instructive sections of the Carboniferous rocks to be seen anywhere in the British Isles.

The oldest rocks seen here represent the upper part of the great series of estuarine deposits referred to previously under the name of the Granton and Hailes Sandstone Group. These most likely correspond in age with the Fell Sandstones of Northumberland, and they are certainly of the same age as the Roman Fell Beds of Westmoreland, and are also coeval with the lower part of the Mountain Limestone of North-west Yorkshire. At the time these strata were in process of formation the Edinburgh Volcano had already ceased to erupt, and, as subsidence proceeded, was buried beneath a pile of newer strata of Lower Carboniferous age. The sea deepened towards the south-east, while in the opposite direction, at a distance as yet unknown, lay the old land. Oscillations of level were taking place, occasionally sufficient in downward extent to admit the sea; but more usually the rate of subsidence did not quite keep pace with that of deposition, so that changes of current frequently took place, and during the growth and advance of the delta large areas were frequently converted either into lagoons or else were for a time laid dry.

In consequence a considerable variety of petrographical characters may be observed in these rocks. Amongst these are some curious bands of strata contemporaneously brecciated, which remind one of the "Broken Beds" of the Portland Oolite. The two other features of special interest are the Calcareous bands which represent the Burdiehouse Limestone and the Oil Shales. Of this latter type of rock one band has been worked for commercial pur-

poses close to the Binn of Burntisland. Oil Shale consists essentially of shale which is more or less saturated with bituminoid matter capable under distillation of yielding paraffine and other hydrocarbons. The rock may be known by its somewhat leathery aspect, by its slight flexibility, and by its giving a more or less shiny streak when it is cut. This kind of rock has probably originated through the partial dissolution of the compound forming the vascular tissues of plants, which, while undergoing maceration in a lagoon, have been acted upon by water containing sulphate of lime in solution.* The Burdiehouse Limestone consists essentially of carbonate of lime both mingled and interstratified with fine laminæ of the same material which forms the Oil Shales.

Soon after the Burdiehouse Limestone was formed, and evidently while the land was slowly subsiding, a volcano broke out on the site which is now occupied by the Binn of Burntisland. It may be remarked here that it must not be supposed from this that the Binn, which bears no small resemblance to an actual volcano, in any way represents the volcano itself. This hill may be said to bear the same relation to the volcano in question that the bole of a tree does to its branches. It is merely a neck, exposed by the denudation of the overlying strata and left in relief because it consists of material of a more durable nature than that of the strata surrounding it. It was certainly from this and some smaller vents around, some of which are well seen nearer Kingorn, that a pile of lavas and tuffs of basic composition, and of a collective thickness amounting to nearly as much as two thousand feet, was emitted.

The general nature of the eruptive material is exhibited in a remarkably fine manner along the coast extending from Burntisland, past Pettycur Point and Kingorn, to about half way from this latter place to Kirkcaldy.

A detailed account of this coast section will be found in Sir Archibald Geikie's *Ancient Volcanoes of Great Britain*, vol. i, p. 440, and again at p. 470. In the present outline it will suffice to state that the coast section in question presents us with a remarkably fine and admirably-exposed series of basic lavas with their tuffs, alternating in their lower and earlier formed part with lagoon-formed strata of the age of the Oil Shales; and in their higher and later-formed portion, with sandstones, shales, and coal seams, of estuarine and marine origin, and with bands of pure grey marine limestone belonging to the horizon of the lower part of the Yoredale Rocks. Thus a band of encrinital limestone containing *Productus giganteus* (a fossil which is confined to the zones near the base of the Yoredale Rocks) may be seen in association with the basalt lavas and tuffs which emanated from the old volcano of the Binn.

* See *Trans. Geol. Soc. Edin.*, 1897, "Origin of Oil Shales."

The finest continuous exposure of the lavas is to be seen on the face of King Alexander's Crag near Pettycur.

Amongst the fossiliferous beds occurring interstratified with the lavas and tuffs, and beneath the first grey limestone on the shore east of Kingorn, there is one stratum known as the Abden Bone Bed, beds associated with which have yielded us the following specimens of invertebrata :

Naticopsis variata, *Bellerophon decussatus*, *Sanguinolites abdenensis*, *Edmondia unioniformis*, *Solenomya primæva*, *Myalina gregaria*, *Myalina mytiloides*, *Aviculopecten ornatus*, *Pteronites persulcatus* ; *Streptorhynchus crenistria*, *Productus semireticulatus* *P. mesolobus* ; *Rhabdomeson rhombiferum*, *Synocladia biserialis*.

For the list of Fish represented in the Abden Bone Bed see Dr. Traquair's Note appended to this.

From a higher bed of shale, immediately underlying the second grey limestone on the shore north-east of Kingorn, the equivalent of the Hurlet Limestone (Yoredale), my students working with me have at one time or another found also the following species :

Orthoceras cylindraceum, *Bellerophon decussatus*, *Euomphalus carbonarius*, *Pleurotomaria yvanii*, *Loxonema rugiferum*, *Naticopsis variata*, *Macrocheilus acutus* : *Nucula tumida*, *N. attenuata*, *Leptodomus* sp. *Schizodus* like *salteri* ; *Productus semireticulatus*, *Spirifera trigonalis*, *Rhynchonella pleurodon*, *Athyris ambigua*, *Orthis michelini*, *Streptorhynchus crenistria*, *Lingula squamiformis*, *L. mytiloides*, *Discina nitida* ; *Rhabdomeson rhombiferum*, *Synocladia biserialis* ; *Lithostrotion junceum*, *Zaphrentis* sp., *Chæteletus tumidus*, *Archæocidaris urei*, *Poteriocrinus crassus*, etc.

Amongst the intrusive rocks formed probably in connection with this volcano are several sheets of dolerite, well seen around Burntisland and near Kirkcaldy. One excellent example of Picrite is seen at Colinswell, where the existence of this lithological type of eruptive rock does not appear to have been recognised until the writer called official attention to its occurrence there. It is remarkable (like the Picrite at Barnton) for its pseudobedded structure, which in both cases is probably due partly to mineral separation and partly to movement during consolidation ; and is likewise noteworthy, as in the case just described, for its fine exemplification of the "chilled edge" it shows against the rock into which it is intruded, as well as for the discharge of colour which has ensued in all cases where a basic eruptive rock has been intruded into strata containing much carbonaceous matter. The Iserine found in the normal rock has given place near the contact to other forms of iron, which, through the action of the carbonaceous reducing agent, have passed from the form of a dense dark colouring ore of iron to one which possesses little or no colouring power, and therefore, leaves the strata in the condition of "white trap."

A very fine and instructive example of the same nature is to be seen at Dodhead Quarry, east of the Binn, where a basic intrude, which cuts across the stratification of some carbonaceous rock, has had its iron reduced while the rock was in a molten state, and has consequently assumed an appearance so much like that of sandstone that, in the old days of the rival Neptunists and Plutonists, it used to be cited as an example of a rock of sedimentary origin which was actually intruded as such into its present position.

Amongst the minerals occurring in this part may be mentioned Analcime, of which good crystals may sometimes be obtained close to the Abden Shipyard at Kingorn, Natrolite, Saponite, Celedonite, Amethystine Quartz, Pearlspar, Goethite, and a few others. Hydrocarbons occur in connection with several of the neck rocks.

V.—THE BRAID AND BLACKFORD HILLS.

No outline of the geological history of Edinburgh would be complete that did not include some reference to the modifications of the surface features connected with the later changes of climate and elevation. In some respects the best general idea of these features can be obtained by visiting the Braid and Blackford Hills, whence also may be had the finest of the many fine views of the "grey metropolis of the north." These hills form the northward termination of the Pentlands. In internal structure they consist of eruptive rocks of Lower Old Red Sandstone age. Their physical structure has already been referred to incidentally as arising from their having been the core of an anticline affecting Carboniferous rocks, from which core those Carboniferous rocks, more easily wasted than the underlying core, have been removed by denudation, leaving the upridged portion of their original floor in the shape of a semi-ellipsoidal mass. Concurrently with the removal of the Carboniferous rocks (some 12,000 feet in thickness) from the summit of the dome, the Braid Burn (or its ancestral stream) has gradually worked down to its present level,* thereby severing the dome into two massifs of smaller size—the Blackford Hill and the Braids.

The northern massif (the Blackford Hill) consists of a pile of andesite lavas, with thin partings of tuff, which are inclined at about fifteen degrees towards the north-east. The lavas naturally tend to form escarpments which face in the opposite direction. This feature can be well seen at the west end of Blackford Hill

* The Braid Burn presents one of the most instructive instances known (not even excepting the rivers draining northward from the Weald) of a small stream of feeble eroding power, preferring to cut its way across what must at one time have been a continuous ridge of very hard rock, instead of taking what is now the easier course seaward, and flowing past Colinton House into the Water of Leith. At the point mentioned the watershed between the former levels of the two streams is now not more than about ten feet in height.

where seen from Morningside Road Station, and, in a less striking manner, where the Blackford Hill is viewed from the south, as from the Braids. From both points of view the trend of these escarpments forms a considerable angle with the course of the Braid Burn.

The Braid Burn had excavated this channel into something like its present form prior to the Glacial Period, as is proved by the occurrence of glacial striæ at the bottom of the valley, and also by the occurrence, within the valley, of a thick mass of glacial drift containing far-travelled boulders. Near the climax of the Glacial Period the great ice-sheet slowly moved over this part in a general east-north-easterly direction (*i.e.*, nearly parallel to the course of the Braid Burn, and in a direction forming a considerable angle with the outcrop of the lavas), and continued to move in that direction for a period of considerable length, if one may judge by the magnitude of the resulting effects. It is certain that the erosion accomplished by the prolonged movement of a sheet of ice which (seeing that it has glaciated the very highest ridges of the Pentlands) could not have been less, and may well have been much more, than two thousand feet in thickness, and whose lower portions were densely charged with stones, grit, and mud, very considerably modified the surface-configuration which resulted from subaerial erosion in pre-glacial times.

Subaerial erosion would almost certainly give rise to nearly-continuous escarpments, in the cases like the present, where lava streams were based upon the more-easily wasted tuffs; and the cross section of each escarpment formed under such subaerial conditions would be rounded at its upper part into the form of an hyperbola. Glacial erosion considerably modified all that. Instead of continuous escarpments, those formed by the lava streams at the Blackford Hill are traversed by wide and deep furrows of a size sufficiently great to be almost entitled to be termed valleys. Instead of escarpments whose cross section formed a double curve, convex at the top edge of the lava, glacial erosion actually *undercut* the crags in many cases, leaving eventually a feature quite unlike any that could possibly arise from any form of erosion by subaerial causes.

If we commence the study of the Blackford Hill by viewing it first from the Braids this combination of features soon begins to impress us, and the longer the features are studied the more apparent does it become that we are regarding the work of ice superimposed upon features of subaerial origin. If, now, we change our point of view and take our stand upon the Blackford Hill and thence study the Braids in the same manner, features of the same kind, but on even a more striking scale, begin at once to attract our attention. The features referred to consist of a series of great east-and-west grooves of considerable magnitude, large enough in some cases to be entitled to be termed valleys.

These grooves have attracted considerable attention from geologists since the earlier part of the present century. Sir James Hall,* Hay Cunningham, Robt. Chambers, Charles Maclaren, Dr. Buckland, Sir Roderick Murchison, Louis Agassiz, and others, have all noticed them, and have speculated much upon their origin. If such features were confined to this neighbourhood, and to these particular rocks, we might get over the difficulty about their origin by attempting to explain it as being in some way connected with the nature of the rock out of which they are carved, as, in fact, Murchison actually did do. But a glance at the adjacent Craiglockhart Hills, which are totally different both in structure and in age, shows us that similar features exist also there. Moreover, the whole north-west face of the Pentlands is grooved and furrowed in much the same way. So, too, is the dolerite mass of Stirling Castle ; so also is Binney Crag in Linlithgow. Again we meet with the same features on Arthur's Seat, and on the Calton Hill. Many years ago Sir Archibald Geikie pointed out surface features of the same kind on the Garleton Hills in Haddingtonshire, and called attention to similar grooves traversing the maritime parts of Berwickshire and East Lothian.

Sir Archibald appears to have been the first to speculate whether ice may not have been the agent to which the Berwickshire grooves are due. It is absolutely impossible to explain them in any other way than by the eroding agency of a thick mass of ice charged with detritus and slowly grinding its way over the rock surface throughout a period of considerable length. It will be seen in every case that the directions of the longer axes of these great furrows coincide more or less closely with the directions of movement of the ice in the same district, as shown by the trend of the glacial striæ. Cumulative evidence of this kind, especially when further strengthened by a considerable body of collateral evidence, cannot fail to lead any unprejudiced geologist to the conclusion that the furrows in question are, like the smaller grooves which accompany them, simply the work of ice. I have gone further even than this, and have ascribed the great grooves which flank the ridge upon which stand the High Street, the Lawn Market, and the Castle Hill, of Edinburgh, as features which are due also to glacial action and to little or nothing else.†

If now we return to the Braid Hills and examine the grooves on the ground, we shall be at once struck by the fact that here, as in so many other cases (Samson's Grave, on Arthur's Seat, for example), these grooves do not present a uniform seaward gradient along their "thalwegs," but, on the contrary, they locally descend considerably below, and beyond that rise above that general

* See Murchison's *Address to the Geological Society of London*, 1842, pages 57, 58.

† See Goodchild, "Glacial Furrows," *Glacialists' Magazine*, 1895.

gradient. In other words, these grooves consist here, as in so many other localities, of chains of rock-basins connected by intervening depressions. How such features are to be explained by any other than by glacial action, I leave to others to answer who have wider field-experience than I have. There can be no question about ice having been in them, for good glacial striæ exist in them at several places on the Braid.

Connected with this part of the subject is the remarkably-fine glaciated surface exposed close to the Braid Burn, on the south side of Blackford Hill, between the two great quarries there, and right and left of the quarrymen's tool-house. This is the glaciated surface which, when visited by Agassiz on the 20th of October, 1840,* in company with Charles Maclaren, was at once recognised by Agassiz as being the work of land-ice. The foundations of our modern beliefs in such matters were therefore laid, so to speak, at this very spot.

A study of this remarkably-glaciated surface will do much to convince almost anyone that it is, and can be nothing else than, the work of land-ice. The rock-surface is considerably undercut, and, indeed, at one point the aspect of the glaciated surface is actually directed towards the centre of the earth; moreover, the striæ go in and out of all the minor depressions, and are not merely confined to the projecting parts of the surface.

Evidently what has happened has been that land-ice, originating in the Dumbarton, Perth, and Argyllshire mountains, has slowly worked its way up the Clyde Basin, over the water-shed into the Basin of the Forth, and then flowed across the Pentlands and along the Braid Burn for a considerable length of time. As the ice moved it eroded its channel more readily where it encountered a softer bed, such as a bed of tuff, and hence, in the long run, it *undercut* the escarpments of lava shaped by preglacial weathering. Then, when climatal conditions ameliorated, through the admission of the warm surface currents of the Atlantic into the North Sea area, in consequence of subsidence, the precipitation on the east of Scotland took the form of rain instead of snow. Under these climatal conditions the glaciers no longer grew, but began to melt away on the spot without making any further advance; and the stones and mud included *within* the ice were melted out as a kind of sediment, thereby giving rise to the various forms of glacial drifts.† This englacial drift filled the lower hundred feet or so of the valley of the Braid Burn, and its remains may be seen even yet on the south bank of the stream opposite the glaciated surface. Then the Braid Burn re-established its former course, and began cutting down through the boulder clay nearly to its

* Dr. Buckland soon afterwards described this Blackford Hill section in the same connection in a communication to the Geological Society of London.

† See J. G. Goodchild "On Drift," *Geol. Mag.*, 1874, where the theory of the englacial origin of Drift Deposits was first published.

old channel, keeping close to the north side of the valley in doing so, and thereby re-exposing the glaciated surface as the protecting cover of clay was removed. Traces of small alluvial deposits left by the Braid Burn, when flowing at higher levels, remain on the face of the rock even yet, and are among the many interesting things to be seen there. Since the close of the Glacial Period the weather has renewed its attacks upon the rock surfaces, and is slowly, but surely, restoring them to something of the same aspect that they presented before the advent of glacial conditions.

A word must be added here, in conclusion, regarding the MINERALS to be obtained at the Blackford Hill Quarry. The decomposition of the andesite lavas where these are *vesicular* (which is not the case here) gives rise to complex products of secondary origin, such as celedonite, agates, natrolite, and other minerals. Here, however, these decomposition products are carried downward in solution through the body of the rock, only into joints and other divisional planes, along which they are subsequently re-deposited rather in the form of veins and strings than in the form of agates. Amongst these minerals so deposited may be mentioned fine examples of Quartz, including the amethystine form, Jasper, Carnelian, Chalcedony, Purple Chert, Pimelite; fine dendrites of Manganese, Goethite (rubinglimmer), Pearlspar, Calcites of interesting crystalline forms, and various other minerals.

The gradual transition from the almost resinous form of the undecomposed andesite lavas (showing well-marked fluxion-structure) into the crumbling mass of rusty clay, which results from the decomposition of these lavas, is one of the most instructive features to be studied in the Blackford Hill Quarry.

LIST OF THE FOSSIL FISH-REMAINS OCCURRING IN THE BONE BED AT ABDEN, NEAR KINGHORN, FIFESHIRE.

By R. H. TRAQUAIR, M.D., LL.D., F.R.S., F.G.S.

[Read July 2nd, 1897.]

ELEVEN years ago, when Mr. William Anderson, now of the Geological Survey of India, submitted to me a collection of fish-remains from the Abden Bone Bed, I furnished him with a list which he inserted in a paper on the bed in question, which he read before the Geological Society of Edinburgh.* Mr. Anderson's paper was also accompanied by a short note by myself upon the bearing of the Abden fossils on the question of the

* Notes on the Fish Remains from the Bone Bed at Abden, near Kinghorn. *Proc. Geol. Soc., Edinb.*, vol. v, 1886, pp. 310-314.

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occurrence of marine and estuarine fish-remains in the Lower Carboniferous rocks of Scotland.*

As our knowledge of Carboniferous fishes has very considerably increased since the year 1886, the list in question certainly requires revision; the principal alteration being due to my having been able to correlate two of the selachian teeth with one of the spines as belonging to one and the same species. The list, as it stands at present, is as follows:

ELASMOBRANCHII.

- Diplodus parvulus*, Traq., tooth.
- Tristychius arcuatus*, Ag., spines.
- Euphyacanthus semistriatus* (Traq.), spines.
- Helodus falcatus*, Traq., spines and (?) teeth.
- Oracanthus armigerus*, Traq., spines and teeth.
- Caliopristodus pectinatus* (Ag.), tooth.
- Cladodus mirabilis*, Ag., tooth.
- „ sp. indet. teeth.
- Acanthodes*, sp. spines.

TELEOSTOMI.

- Rhizodopsis*, sp. scales and head bones.
- Strepsodus striatulus*, Traq., teeth.
- Megalichthys*, sp. scales.
- Cœlacanthus abdenensis*, Traq., head bones.
- Elonichthys pectinatus*, Traq., scales.
- Eurynotus crenatus*, Ag., scales and head bones.
- Cheirodus crassus*, Traq.

Remarks on the Species.

Four species are here recorded which were not in my previous list, namely: *Diplodus parvulus*, *Euphyacanthus semistriatus*, *Cladodus mirabilis*, and *Cœlacanthus abdenensis*.

From the list I have deleted *Strepsodus* (*Archichthys*) *portlocki*, *Helodus* (*Pleurodus*) *woodi*, *Pœcilodus elongatus*, and *Deltoptychius* sp., for the following reasons:

The tooth previously attributed to *Strepsodus portlocki* (Ag.) seems to me now not to differ materially from those of *S. striatulus*, Traq., which occur in the same bed.

Careful examination of the types of *Helodus* (*Pleurodus*) *woodi* (Davis) has convinced me that the small inrolled teeth, common in the Abden bed, do not belong to that species. They more

* Remarks on the Fossils of the Bone Bed at Abden. *Ib.*, pp. 314-315.

resemble the teeth of *H. (Pleurodus) attheyi* (Barkas), but as they are associated here with a very distinct Helodont spine, *H. falcatus*, Traq., we may provisionally correlate them with that spine.

Pæcilodus elongatus, Traq., and the tooth which I referred to as *Deltoptychius* sp., form undoubtedly the dentition of the fish, allied to the Permian *Menaspis*, whose head was furnished with the spines to which I gave the name of *Oracanthus armigerus*.* Of the two forms of tooth the *Deltoptychius*-like one forms the palatal, and the apparent *Pæcilodus* the mandibular, dentition of the fish in question.

To the remains of *Acanthodes*, *Rhizodopsis*, and *Megalichthys* occurring in this bed I am still unable to attach specific names.

Remarks on the Conditions of Deposit.

As is already known, the fish remains of the Abden Bone Bed are remarkable for the absolutely fragmentary condition in which they occur. I myself have not seen one single instance of two separable bones or teeth being found in apposition.

The species of fish occurring in this bed are mostly of an estuarine character, such as *Eurynotus crenatus*, *Tristychius arcuatus*, *Euphyacanthus semistriatus*, *Acanthodes*, *Strepsodus striatulus*, *Elonichthys pectinatus*, *Callopristodus pectinatus*, *Diplodus parvulus*. Others are more decidedly marine, such as *Oracanthus armigerus* and *Helodus falcatus*. But as yet only one truly marine fish-remain has occurred, namely, a tooth of *Cladodus mirabilis*, so that the prevailing facies of the deposit is, so far as the fishes are concerned, decidedly estuarine.

EXCURSION FROM BATHGATE TO LINLITHGOW.

By PROF. JAMES GEIKIE, LL.D., D.C.L., F.R.S.L. & E., F.G.S.

[Read July 2nd, 1897.]

THE railway to Bathgate traverses the Calciferous Sandstone series of the Carboniferous System. That series consists of two groups of strata, namely, (1) *The Red Sandstone group*—a set of reddish, yellowish, and white sandstones, with associated shales and clays; and (2) *The Cement-stone group*, comprising white and yellow sandstones, and blue and black shales, which now and again contain seams of limestone, cement stone, clay-ironstone, and thin coals. It is this latter group which has yielded most of

* Notes on Carboniferous Selachii, *Geol. Mag.* (3), vol. v, p. 85, 1888.
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the building stones used in Edinburgh. The bituminous shales of the group have long been worked for the production of mineral oil. The seams of limestone and coal, however, are generally too thin to be of economic importance—the only seams which have been assiduously worked being the Burdiehouse or Queensferry limestone and the Houston Coal.

The general dip of the strata between Edinburgh and Bathgate is westerly, but at a low angle, and the strata frequently undulate, thus giving rise to tortuous outcrops, and many small basins.

Contemporaneous basalts and tuffs occur low down in the Calciferous Sandstone series, and another set of similar rocks makes its appearance towards the top of the series, as will be pointed out more fully in the sequel.

The strata are again and again traversed by sheets of intrusive rock (Dolerite, Diabase, Basalt), and pierced by necks of volcanic agglomerate and tuff, with which basalt is now and again associated.

The youngest igneous rocks of the district are dykes of basalt, which have a prevalent east and west trend. The most important faults of this region run approximately from north-east to south-west. The whole region is covered to a less or greater depth by boulder-clay, which here and there is overlaid by kames and sheets of gravel and sand.

The ground to be visited by the excursion lies almost wholly within the Carboniferous Limestone area. It may be as well to note here that this series in Scotland is divisible everywhere into three well-marked groups, which are as follows :

3. White sandstone, with grey, blue, and black shales, associated with which are usually three thin marine limestones and occasional workable seams of coal and ironstone.

2. White sandstones and dark shales, with many workable seams of coal and ironstone.

1. Sandstones and shales, usually with three limestones, one of which (Hurlet or Main Limestone) has an average thickness of 8 or 9 feet. This is the most important of the Scottish limestones. Now and again it thickens out to 90 or 100 feet (Ayrshire). In the Bathgate Hills it reaches a thickness of 70 or 80 feet. Seams of coal, usually very thin, and bands of clay-ironstone are met with in this group.

In the Bathgate and Linlithgow district the Limestone series contains many bedded basalt-rocks and tuffs. It is the presence of these, in fact, which gives its chief interest to the district—it is noteworthy that no trace of similar volcanic action is met with in the contemporaneous strata of Midlothian on the one hand, or in those of Dumbartonshire on the other. For convenience of mapping, the Hurlet Limestone has generally been taken as the base of the Limestone series.

series. But now and again one or more thin seams of marine limestone occur on a somewhat lower horizon. In the Bathgate Hills, for example, an encrinital limestone occurs at a depth of more than 100 feet below the Hurlet seam, so that in this district marine conditions had set in before the accumulation of the Hurlet Limestone had commenced. The lowest limestone, just referred to, is seen at Whitebaulks and Tartraven towards the north end of the Bathgate Hills, where it rests directly upon a thin seam of coal. As the limestone, with its associated sandstone and shales, is followed southward, the accompanying strata gradually thin away until at Kirkton, near Bathgate, the limestone is underlaid and overlaid directly by volcanic rocks. As the underlying basalts and tuffs attain a thickness of several hundred feet, and towards the north end of the hills are interstratified with the true Calciferous Sandstone series, it is obvious that the volcanic conditions, which are characteristic of the whole Limestone series, must have commenced in Calciferous Sandstone times.

Intercalated among the volcanic rocks which underlie the lowest marine limestone appears a remarkable bed, which Dr. Hibbert considered to be a deposit from thermal springs in the vicinity of some volcano. The bed in question is a limestone of very unequal thickness, varying as it does in a few yards from 5 or 6 feet to 10 or 12 feet. It is a hard grey rock, laminated for the most part, and abundantly charged with black chert. This occurs in numerous laminae, which are often contorted and brecciated. Not infrequently the chert forms larger and smaller irregular concretionary masses. The only fossils met with are a few traces of coal plants.

Unfortunately, the section in Kirkton Quarry is now so overgrown that very little is seen; and the same, alas! is to be said of most of the old quarries seen in the Bathgate Hills. It may be interesting, however, to note here the section seen at the north end of Kirkton Quarry when it was visited by the Geological Survey:

Columnar Basalt.

Shales and sandy beds, tuffaceous towards the top. Plants abundant and well-preserved, including *Lepidodendron*, *Stigmaria*, *Pecopteris*, etc.

Limestone, finely laminated, occasionally showing much twisting and contortion.

[Space obscured by herbage and *débris*.]

Alternations of Tuff and Limestone.

Limestone, laminated, cherty.

Band of tuffaceous Limestone and Tuff.

Concretionary Tuff.

Basalt rock.

The section varied considerably in different parts of the quarry. The explanation adopted by the Survey is practically that suggested by Dr. Hibbert.

The dip of the strata throughout the district is persistently towards west. Proceeding in that direction from Kirkton we pass over a thick bed of basalt and reach the lowest marine limestone. Here the bed rests upon bedded, fine-grained tuff, and is shaley below and somewhat tuffaceous towards the top. Above this come beds of tuff and shale, and these are overlaid by limestone with thin partings of tuffaceous matter, after which follows a bed of basalt. Encrinites and corals are common in the limestone; but the sections are now almost wholly obscured.

Still walking westward, we traverse basalts until the outcrop of the Hurlet Limestone is reached. This bed was formerly extensively worked, and the long line of quarries still afford sections in which the character of the rock may be seen. In some places it is immediately underlaid and overlaid by tuff; in other places shales and sandstones separate it from the volcanic rocks above and below. The thickness of the limestone varies, the maximum being 80 feet. In the aqueous strata associated with it, seams of coal and fireclay occur. At the north end of North Mine Quarry the following section was formerly well displayed :

Basalt.

Black Shale.

Tuff, yellowish green.

Tuff, blueish, with rounded fragments of altered sandstone and limestone.

Grey Sandstone with *Stigmaria*.

Coal, with *Stigmariæ* on upper surface.

Fireclay.

Limestone.

This association of coal and fireclay with marine limestone is one of the most interesting characteristics of the Scottish Carboniferous Limestone Series.

The strata above the Hurlet beds consist of a great succession of basalts, with intercalated layers of tuff, shale, and sandstone, overlying which comes a relatively thick set of sandstones and shales containing four workable coals. This is the "middle group" of the Limestone Series. The "upper group" immediately succeeds it to the west, and in this group the last of the contemporaneous basalts makes its appearance. Both of these groups crop out at the foot of the Bathgate Hills, where they are largely obscured under boulder-clay, etc.

The contemporaneous igneous rocks of the district attain their greatest thickness at a point rather more than half-way between Bathgate and Linlithgow. A few miles south of Bathgate they are represented by only one or two beds of basalt. In a northerly

direction they continue beyond Linlithgow, and are well-developed in the coal-field of Borrowstowness.

The intrusive rocks of the district are represented by sheets, dykes, and necks. One sheet is traversed by the excursion about a mile or so north of Kirkton Quarry. Several of the east and west dykes also are crossed, and can be studied in detail—one of them cutting through a volcanic neck.

Metalliferous veins have been worked in the heart of the Bathgate Hills. Argentiferous galena appears to have been obtained in some quantity at a very early period. The mines were reopened some twenty years ago, and found to be extensive; but the new working was unremunerative.

The glacial phenomena of the district do not call for any particular notice. Rock-striæ are seen now and again; in one place a vertical face of rock being well-smoothed and striated. The direction of glaciation is from west to east, shown both by rock-striæ and the "carry" of the stones in boulder-clay.

EXCURSION FROM ST. MONANS TO ELIE.

By PROF. JAMES GEIKIE, LL.D., D.C.L., F.R.S.L. & E., F.G.S.

[Read July 2nd, 1897.]

THE Section along the sea coast between St. Monans and Elie gives excellent exposures of the lower group of the Carboniferous Limestone Series, and the underlying Calciferous Sandstone Series. It also cuts across a number of volcanic necks—the composition and structure of which, and their relation to the adjoining rocks, can be studied in detail.

The excursion will visit first the lower limestones on the beach at St. Monans. The strata are here arranged in a sharp syncline with an intermediate subordinate anticline.

About one mile to the east of St. Monans the junction of the Limestone series and the immediately underlying Calciferous Sandstone series is well exposed, the beds dipping at angles of 45° – 50° towards north-west. The lower series consists of white, yellow, and reddish sandstones, fine conglomerate, and black and purple shales, with some thin seams of coal and limestone.

The overlying Limestones (Carboniferous Limestone Series) are four in number, the most important bed being the third lowest of the series. The Limestones are, as usual, interstratified with shales and sandstones. Overlying the Limestones are sandstones and shales containing two coals and an overlying Limestone.

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These are the highest strata seen upon the beach. West of the Harbour of St. Monans the lower Limestones again crop out, with a strong dip to the east.

The fossils obtained by the Geological Survey from these Limestones are as follows: *Lithostrotion*, *Aulophyllum*, *Chætetes*, *Ceriodora*, *Fenestella*, *Poteriocrinus*, *Griffithides eichwaldi*, *Eurypterus hibberti*, *Productus semireticulatus*, *P. longispinus*, *P. scabriculus*, *Chonetes laguessiana* (*C. hardrensis*), *Rhynchonella pleurodon*, *Spirifera duplicicosta*, *S. trigonalis*, *Orthis michelini*, *Ctenodonta gibbosa*, *Myacites sulcatus*, *M. costellatus*, *Bellerophon urii*, *Orthoceras annulare*.

At St. Monans the first of the necks puts in its appearance. It consists of agglomerate and tuff of the usual character, and is traversed by dykes and squirts of basalt. On the west side of this neck the Carboniferous Limestone Series again crops out. The strata are curved in somewhat sharp anticlines and synclines, and the beds are consequently repeated. They show two thin seams of limestone—the associated shales being rich in fossils—amongst which may be mentioned: *Productus*, *Lingula*, *Myacites*, *Schizodus*, *Solenomya*, *Aviculopecten*, *Edmondia*, *Nautilus*, *Amblypterus*, *Rhizodus*, etc. Plants are also more or less common both in shales and sandstones.

Between St. Monans and Newark Castle the Limestone series is again broken through by a small neck, which measures hardly more than 50 yards by 35 yards across. In the immediate vicinity of this and the other necks the strata are usually jumbled, and often turned over sharply as if dipping into the neck.

Immediately west of Newark Castle another small neck is seen, cutting through disturbed beds of sandstone and shale. A little further to the west we encounter one of the largest necks—that of Coalyard Hill. Dykes and veins of basalt and “white trap” are associated with it. Along the margin of this neck the strata are often much contorted, and here and there they stand on end. On the beach below Ardross, sandstones and shales with clay ironstone are overlaid by sandy fireclay, full of rootlets, coal $2\frac{1}{2}$ ins., blue clay 9 ins., and limestone 1 ft. 8 ins. Above these come blue shales crowded with crinoid stems and other fossils. The whole section is capped by the shelly gravel of a raised beach.

Proceeding westward we now traverse sandstones which bend over suddenly towards another large neck, traversed by basalt dykes as usual. Crossing this neck we reach an area of much broken and hardened sandstone, and shortly afterwards encounter a somewhat smaller neck of much the same character as those already visited.

Further to the west we come upon one of the most interesting necks of the district—that of Shepherd Law. The junction between the neck and the sandstones and shales is very clearly

displayed, the strata being jumbled and altered, and turned up on end or bent backwards towards the neck. The strata through which the neck of Shepherd Law has pierced are believed to belong to the Calciferous Sandstone Series. A little to the west of it one of the lower encrinital limestones again appears. Before this limestone is reached a broad intrusion of dolerite is seen. At Elie Harbour yet another neck is displayed. No other neck seen upon the coast shows better the various characteristics of this volcanic structure. The junction line is excellently exposed, and shows how the strata are turned on end and bent inwards to the neck. In places the sandstones are baked into quartz rock, and the strata much jumbled and shattered. The internal structure of the neck itself is interesting, showing, as it does, the general centro-clinal dip of the agglomerate.

Probably time will not suffice to go beyond this point. But if possible the large intrusion of columnar basalt at the west end of Earlsferry should be visited. The chief points to be noticed are the columnar structure, and the change which the basalt undergoes at its point of junction with the sandstones and shales. In contact with the former it is usually rendered somewhat soft, and assumes a brownish colour, while where it comes on the black shale it passes into "white trap."

On the shore at Elie appears a bed of clay charged with arctic shells; smaller and larger erratics, some of them scratched, occur in the clay—amongst the erratics being nodules and fragments of flint. Amongst the shells obtained from the clay are: *Saxicava rugosa*, *Thracia myopsis*, *Tellina proxima*, *Astarte compressa*, *Crenella decussata*, *Leda arctica*, *Pecten grænlandicus*, *Turritella polaris*, *Natica grænlandica*, *Nucula tenuis*, var. *inflata*.

Three well-marked raised beaches can be followed in the Elie district. The lowest one (25-30 feet), however, is largely obscured by a covering of blown sand. The middle one (50 feet beach) is much more readily traced—forming a broad terrace. The highest (100 feet beach) here and there makes a feature at the surface, but it is much washed down, and the limits of the terrace are hardly traceable continuously for any distance.

On the western side of Kinraig Hill, two miles west of Elie, a succession of old sea-cliffs is well seen. These occur at the following approximate levels: 25-30 feet, 50 feet, 75 feet, 100 feet, 150 feet.

THE STIRLING DISTRICT.

By HORACE W. MONCKTON, F.L.S., F.G.S.

[Read July 2nd, 1897.]

It is proposed to devote one day of the excursion to Stirling, and thus afford an opportunity for the comparison of the rocks on the western side of the Stirlingshire Coalfields with those of Midlothian and Linlithgow.

The district has already been dealt with at some length in our PROCEEDINGS,* and the diagram section (Fig. 2) is reproduced from the former paper. The line of section passes in an almost east and west direction through a point about three miles south of Stirling Castle. This is close to the south edge of Sheet 39 of the Geological Map, and consequently the explanation of Sheet 31, which joins on to the bottom of Sheet 39, will be found useful, for as yet no explanation of Sheet 39 has been published amongst the Memoirs of the Geological Survey.

The most prominent natural features at and near Stirling are the basaltic crags upon one of which the Castle stands. These crags are formed of intrusive dolerite, which is indicated by a most conspicuous colour on the Geological Map. The particular crag selected for examination by our members during the excursion is known as the Sauchie Craig, and is shown in the diagram section Fig. 2. It has been quite recently dealt with at some length in the *Quarterly Journal* of the Geological Society, vol. li, p. 480 (1895), and a few words will therefore suffice for it now.

The rock is fairly coarsely-crystalline, and the microscope shows it to be composed of (1) a plagioclase-felspar, probably labradorite, often well-preserved and of very variable size, sometimes 0·35 inches long—perhaps 0·08 × 0·015 inch may be taken as a fairly common size amongst the larger crystals; (2) Augite also frequently very fresh; (3) Iron oxide (Hæmatite or Ilmenite) fairly abundant; (4) Biotite, which occurs in small flakes but is not common; (5) Long needles, usually identified as apatite.

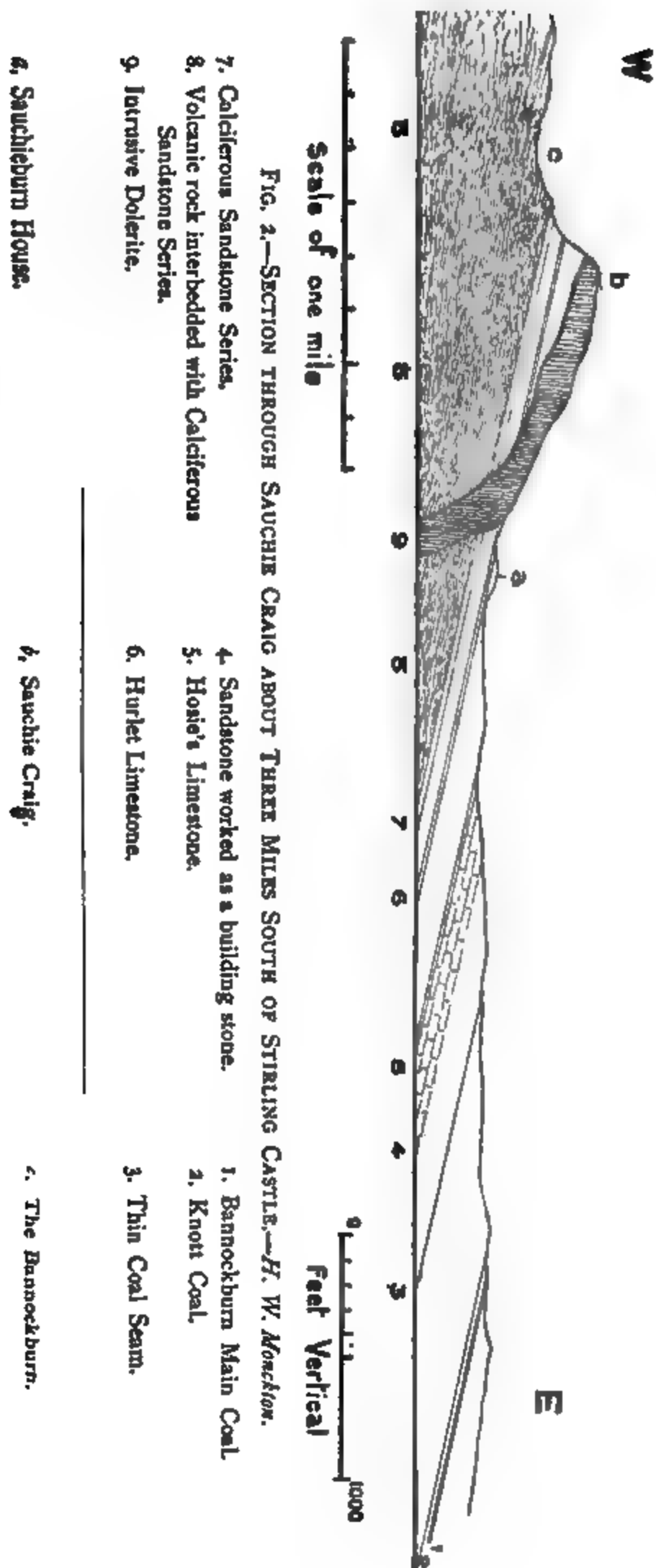
There are also in some cases a few small flakes of hornblende and some grains of quartz, perhaps secondary, and a good deal of green or brownish-green change product, serpentinous mineral calcite, etc.

The marginal portion is as usual in intrusive sheets finer grained than the centre, and often more or less glassy, and has been described in detail in the paper in the *Quarterly Journal* already cited.

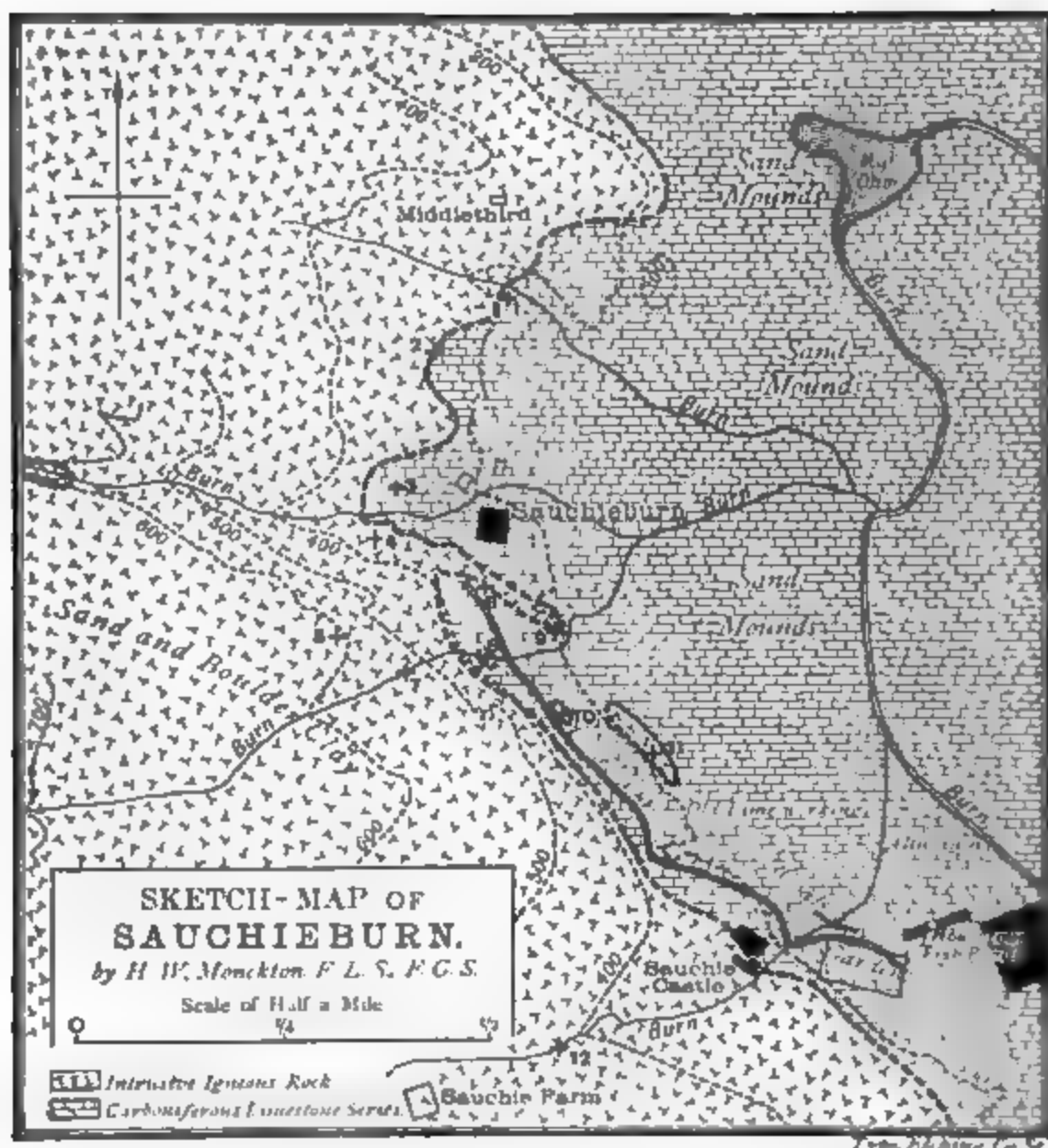
Evidence in favour of the intrusive character of the dolerite is

* Vol. xii, p. 242 (1892).

THE STIRLING DISTRICT.



furnished by the altered condition of the stratified rocks in immediate contact with it both at the top and bottom, and in several places in Sauchie Craig it is seen that the dolerite does not conform to the bedding of the underlying strata, and in at least one place a mass of strata is more or less involved in the



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FIG. 3.

igneous rock. At Sauchieburn too, there appear to be two or more small sheets of igneous rock below, but in connection with the main mass of the dolerite. They are indicated on the sketch-map (Fig. 3).

This intrusive rock is classed by Sir Archibald Geikie with the Carboniferous Puys, and he gives the date of intrusion as about the period of the Carboniferous Limestone.*

* *Quart. Journ. Geol. Soc.*, vol. xlviii; *Proc.* pp. 125, 142 (1892).

The junction of the intrusive igneous rock with the underlying shales is very well seen in Sauchie Craig, and the members of the party will be able to examine it closely. The igneous rock usually rests on very much altered shale, and at a variable distance below it is the outcrop of the Hurlet Limestone, which occurs close to the base of the Carboniferous Limestone Series. Locally the limestone is known as the Murrayshall Limestone, and it has formerly been largely worked by levels which run far under the intrusive igneous rock.

Associated with the limestone are dark-coloured shales, which in places are crowded with fossils. The following were collected by myself on Sauchie Moor :

Poteriocrinus.

Athyris planosulcata, Ph.

Athyris roissyi, Lèv.

Chonetes laguessiana, de Kon.

Chonetes polita, M'Coy.

Lingula squamiformis, Ph.

Orthis michelini, Lèv.

Orthis resupinata, Mart.

Productus aculeatus, Mart.

Productus costatus, Sow.

Productus latissimus, Sow.

Productus longispinus, Sow.

Productus punctatus, Mart.

Productus semireticulatus, Mart.

Retzia radialis, Phil.

Spirifera glabra, Mart.

Spirifera trigonalis, Mart.

Natica ampliata, Phil.

The limestone and associated shales form the base of the Carboniferous Limestone Series, and below it we find the Calciferous Sandstone, which is here almost entirely represented by contemporaneous volcanic rocks, mapped as "Porphyrite, etc., of Calciferous Sandstone Age." Its horizon is indicated on the comparative sections of Lower Carboniferous Rocks (Plate VI). This rock is seen rising in small hummocks close to the Bannockburn, below Sauchie Craig, and it stretches away far to the west, forming a great area of grouse-moor up to the Gargunrock Hills and the Campsie Fells. It is classed by Sir Archibald Geikie with the Carboniferous Plateaux eruptions.*

As will be seen on reference to Fig. 2, it is the top of the "Porphyrite" which is exposed near Sauchie. In places it is somewhat slaggy in appearance, but for the most part it is a markedly porphyritic basaltic rock, usually more or less changed or decayed.

The porphyritic minerals are (1) Plagioclase, which is sometimes well preserved; (2) Olivine, usually much changed, occurs in all the micro-sections from Sauchie which I have seen, but sometimes is rare and only in small granules; (3) Augite only occurs as a porphyritic mineral in one of my Sauchie slides.

The ground mass is formed of small felspar, iron oxide, and apatite. There are usually more or less calcite, chlorite, and

* *Loc. cit.*, pp. 105-107.

various other change products. In many specimens the flow structure is well marked.

On the Geological Map it will be noticed that the "Porphyrite" is not mapped to the east of the intrusive "Basalt," and when drawing Fig. 2 I had great doubt whether to continue the "Porphyrite" 8 underground east of the Dolerite 9. Eventually I did continue it, though the evidence is not by any means decisive on this point.

To the east of the Sauchie dolerite the Hurlet Limestone was found in a well at Sauchieburn House, and the Hosie's Limestone has been worked between Sauchieburn and Old Sauchie.

The ponds of the Howietown Fishery are partly excavated in the sandstone 4 of Fig 2 and partly in overlying dark-coloured shale. At the chief hatching-house of the Fishery there is an interesting section showing dolerite resting on indurated shale locally known as "calm." If time allows, this section and also the large quarry in the dolerite known as the Millholm Quarry will be visited. The quarry is in the intrusive dolerite, which there contains much pink micro-pegmatite, an account of which will be found in the paper in the *Quarterly Journal* already referred to.

ON THE ORIGIN OF THE HIGH-LEVEL GRAVEL WITH TRIASSIC DEBRIS ADJOINING THE VALLEY OF THE UPPER THAMES.

By H. J. OSBORNE WHITE, F.G.S.

(Read June 4th, 1897.)

I.

IT is a well-known fact that the River Thames, in common with other streams, is bordered throughout its course by deposits of gravel, sand, and loam, which occur in the form of gently inclined sheets and impersistent terraces, of greater or less extent, at varying heights on the slopes of its valley. The area covered by these deposits and the forms they assume vary greatly, being dependent on the size and the shape of the valley, which are, in their turn, very largely determined by the character of the strata in which the valley has been eroded. In the harder and more durable rocks, such as the Oolite Limestones, and the Upper Chalk, the valley is, as a rule, narrower and has steeper sides, and the drifts are consequently more scanty, and with wider vertical intervals between the separate terraces, than in the less resisting rocks, such as the Upper Jurassic and Eocene clays and sands.

The gravel, which constitutes the major part of the valley deposits, contains a mixed assemblage of materials derived directly (and also to a large extent indirectly, by way of the older drifts) from the rocks of the Thames basin. As might be expected from the great variety of the rocks exposed in the region traversed by the river and its tributaries, the relative proportion of the constituents differs greatly in different places. Thus, near the sources of the stream in the Cotteswolds, the gravel is composed chiefly of small, waterworn fragments of Oolitic limestone; near Oxford flints become common, and there is (in the lower spreads, at least) an abundance of the stouter fossils from the Oxford Clay and the Corallian rocks, and fossiliferous pieces of Forest Marble; while lower still, in the London Basin, partially worn flints far outnumber the sum of the other constituents, and we have Lower Greensand chert and ironstone, from the Wealden area, and flint pebbles and sarsenstones from the Eocene beds. In addition to the fragments of the more durable rocks, and less perishable portions of the softer rocks occurring in the region drained by the Thames system there is, from the Oxford district downwards, a large variety of siliceous debris derived from older drifts, which evidently represents the sweepings of a far greater area of country.

AUGUST, 1897.]

Of the sand and loam, or brickearth, associated with the gravel, it is here unnecessary to speak. Taking the valley deposits as a whole, the stratified arrangement they exhibit in sections, the presence within them of freshwater mollusca and plants, mammalian bones, and palæolithic implements, their proximity to the river, and their general resemblance to the alluvium in process of formation at the present day, establish their fluvial origin so completely that few geologists would question the propriety of the term "River Drift" now usually applied to them.

Now while there exists a very general agreement as to the nature of such valley beds, there are considerable differences of opinion with regard to the origin of certain closely related deposits which, though lying for the most part without the limits of the valley proper, have the essential features of the River Drift, into whose highest terraces they, indeed, often merge.

The deposits referred to are those well developed masses of gravel and sand which spread in broad, plateau-like, gently-sloping terraces from the crests of the slopes of the Thames valley up to heights of more than 300 ft. above the level of the stream, between Stanlake, in Oxon, and the Maidenhead district. In the published memoirs and drift maps of the Geological Survey, which include only a small portion of this tract of country near to its eastern limit (Sheet 7), this high level drift has been described and mapped as "Glacial Gravel"—for the reason that (in common with doubtful deposits of the same type) "it seems to occupy the same position as, and either to be, or once to have been, continuous with other masses of gravel and sand beyond our borders which, though underlying the Great Boulder Clay, are shown to be allied to it by sometimes containing a thinner mass of a like stony clay and by sometimes overlying another Boulder Clay."* By the officers of the Geological Survey the line of demarcation between the River Drift and Glacial Gravel is made to coincide, on the whole, with the crest of the slopes of the valley, which is here, as a rule, rather sharply defined; *i.e.* from 100 ft. to 150 ft. above the river. But this line is admitted by Mr. Whitaker† and other observers to be, to a large extent, an arbitrary one—its position being dictated by convenience rather than by objective differences in the deposits separated.

Not only do the higher masses often pass into the lower, as I have remarked, but, inasmuch as the depth and shape of the valley are subject to somewhat rapid changes, it frequently happens that the lower plateaux of the Glacial Gravel in one locality occur at smaller elevations above the river than the higher terraces of the River Drift in another, closely adjacent. Not long since, Mr. Allen Brown drew attention, in our PROCEEDINGS, to a notable instance

* Whitaker, *The Geology of London* (1889), vol. i, p. 299.

† *Ibid.*, pp. 300 and 301.

of this in the drift-covered tract between Maidenhead and Uxbridge.*

So far as outward appearance, internal structure, and general composition are concerned the differences are certainly not such as to justify this separation. The features these "Glacial" beds lend to the landscape are not appreciably different from those to which the larger terraces of River Drift give rise. Indeed, when standing on one of the better developed plateaux one may often find it hard to realise that the river, at its nearest point, is actually running at a level lower by, perhaps, two or three hundred feet. In section, these beds often exhibit the well-marked stratification and alternation of finer with coarser materials characterising the valley deposits; and these on too large a scale to be the result of mere rainwash and trail. It is true that mammalian remains are absent, together with all traces of contemporary mollusca, and fragments of chalk and oolitic limestones, but in this respect these high-level deposits differ not at all from the more elevated beds of acknowledged River Drift; the absence of calcareous material being due, no doubt, in both cases, to the same cause, viz., their long exposure to decalcification by meteoric waters. Palæolithic implements, though scarce, are not unknown in some of the lower spreads.† The chief distinction between the plateau and the valley drifts appears to lie in the greater abundance in the former of the fragments of siliceous rocks foreign to the Thames basin. This contrast is less marked in the Chalk country than on the older terrains farther west, but even here the proportion of the materials referred to is often perceptibly greater in the higher drift. However, whether we turn our attention to the eastern developments, or to the western, the (in all respects) transitional character of the deposits at intermediate elevations compels us to regard the drift of the higher plateaux on the one hand, and of the lower river terraces on the other, as the extremes of a series.

Under these circumstances we are fairly entitled to ask whether the high-level, plateau-forming, gravelly deposits bordering the upper courses of the Thames valley are not just as much the work of fluvial agencies as the River Drift itself.

In the present paper I hope to show that the evidence leaves us little choice but to answer this question in the affirmative.

II.

In the foregoing remarks reference has been made to the presence in the Glacial or Plateau gravel, and its derivatives, of fragments of certain siliceous (quartzose) rocks not exposed in the Thames basin. These materials, which comprise pebbles and small worn boulders of reddish, brown, and grey quartzites, of

* "On the High Level River Drift between Hanwell and Iver," vol. xiv, p. 165.

† Vide references given *Proc. Geol. Assoc.*, vol. xiv, part i (1895), pp. 19 and 20.

white and coloured vein quartz, of yellow, brown, and red grits and sandstones, often micaceous and felspathic, of dark hornstone, lydian stone, dark radiolarian chert, encrinital chert (Carboniferous) and jasper, and, less commonly, of igneous rocks are, in point of interest, and also often of numbers, the most important constituents of this drift.*

Abundant in deposits at all levels they seem to be most numerous, and to attain their largest average individual dimensions, in the higher plateaux in particular, and the more western developments in general. Though some of these materials—viz., the smaller pebbles of vein quartz, jasper, and lydian stone—are found in the still older Westleton Gravel of the region, the great bulk of them make their first appearance in notable quantity in the Plateau Gravel, and in the beds of similar character, at about the same general horizon, which underlie the Chalky Boulder Clay in Herts and Essex. There is, therefore, some reason to think that their introduction was effected by the agencies to which the said deposits owe their existence.

It is generally admitted that the source of much of this foreign débris is to be found in the Lower Triassic rocks of the Midlands—the quartzite pebbles, in particular, possessing all the features characterising those which bulk so largely in the composition of the Bunter Beds.

The earliest general accounts of the distribution of these quartzose materials in the basin of the Thames are those given by Dean Buckland, in a paper dealing with the "Quartz Rock of Lickey Hill in Worcestershire," published in the *Trans. Geol. Soc.* in 1821, and in his celebrated work, *Reliquiæ Diluvianæ*, in 1823. In the latter he remarks† that "the New Red Sandstone formation in the central parts of England contains an enormous deposit of pebbles of compact granular quartz [quartzite]," quantities of which have been dispersed over adjacent districts and mixed with fragments of other rocks, both older and younger than the New Red Sandstone.

He traces these materials from their home, southward across the Lias, and thence, over the watershed of the Severn and Thames, through the gap in the Oolite escarpment in the Cottswolds between Shipston and Moreton-in-the-Marsh, and down the valley of the Evenlode to the junction of that stream with the Thames, near Ensham. A second, and independent, stream of débris, confluent with the first near Oxford, is traced through the depression in the Oolite escarpment by Fenny Compton, and down the valley of the Cherwell. Having passed into the country round Oxford, "these quartzose pebbles," says Dr. Buckland, "have been forced onwards, and mixed up with the

* For detailed descriptions of these stones see H. W. Monckton "On the Occurrence of Boulders and Pebbles from the Glacial Drift in Gravels South of the Thames," *Quart. Journ. Geol. Soc.*, vol. xlix, 1893.

† P. 249.

gravelly wreck of the neighbouring hills in each successive district along the line of the Thames, from the vale of Oxford downwards to the gravel beds of London; their quantity decreasing with the distance from their source. . . .”^{*} He notes that, although they follow the courses of the above-named streams, the gravels thus formed are not confined to the valleys, but spread over the adjoining elevated plains, and cap hills, such as those of Wychwood Forest, Witham Hill, Cumnor Hill, and the chalky summits near Henley.

In a paper “On the Physical Geography and Pleistocene Phenomena of the Cotteswold Hills,”[†] published some thirty years later, Professor E. Hull deals with a portion of these deposits in the north-western quarter of the Thames area, under the title of “Northern Drift,” and supports the views expressed by Buckland with respect to the sources from which the quartzites, grits, etc., have been derived. He remarks[‡] that this drift “has evidently been carried along the Moreton valley and swept over the high ground to the south”; and he shows that it extends over a wider area on the eastern flank of the Cotteswolds than is indicated in Buckland’s account—occurring, in scattered patches, as far south as Cirencester. He notes, also,[§] that the transported fragments diminish numerically the farther south we proceed from the Moreton valley.

In 1869 a further contribution to our knowledge of the composition and distribution of the quartzite-bearing drift of the same district was furnished by Mr. W. C. Lucy, in a valuable paper “On the Gravels of the Severn, Avon, and Evenlode, and their Extension over the Cotteswold Hills.”^{||} In this work the physical characters of the coarser drifts of the northern Cotteswolds are described in considerable detail, and the various deposits are indicated on an accompanying map. In the latter, the Northern Drift of the Severn and Avon valleys is shown to follow the course through the breach in the Oolite range at Moreton into the drainage area of the Thames, which is indicated by previous writers on the subject, except that, in addition to the main mass following the valley of the Evenlode, a second train pursues that of the Windrush, whose head-waters adjoin those of the Evenlode, and there are a few small, disconnected, patches marked to the south of these.

The watershed of the Severn and Thames is about 420 feet above sea-level in the gap at Moreton, but the gravels with Triassic debris are stated to occur in terraces up to an elevation of 750 feet O.D. (their maximum height on the Cotteswolds) near Stow-on-the-Wold and Chipping Norton, on either side of that

^{*} *Reliquiæ Diluvianæ*, p. 252.

[†] *Quart. Journ. Geol. Soc.*, vol. xi, p. 477.

[‡] *Op. cit.*, p. 494.

[§] *Loc cit.*

^{||} *Proc. Cotteswold Naturalists' Field Club*, vol. v, p. 71.

valley. Mr. Lucy bears witness to the great abundance of this Northern Drift in, and on the heights adjacent to, the vales of Moreton and Evenlode; and he also notes the coarseness and large variety of its constituent rock-fragments, which seem, indeed, to be the sweepings of the midland and western counties.

The three independent accounts I have briefly abstracted leave little doubt that the quartzose materials from the Trias and older rocks of the Severn basin, which distinguish the Plateau or Northern Drift gravel and its derivatives in the north-western quarter of the Thames area, have been transported through the depressions or gaps in the great escarpment of the Inferior Oolite at the heads of the valleys of the Evenlode and Windrush, near Moreton, and of the Cherwell near Banbury, and spread, together with post-Liassic detritus from local sources, over the country to the south and south-east along the courses of those streams, down to their junction with the Thames in the "Vale of Oxford," where the distinct trains coalesce to form the high level deposits which border the valley of that river. In the words of Dr. Buckland, ". . . the quartzose pebbles are scattered in an almost uninterrupted line, marking distinctly the course by which they have been propelled from Warwickshire into the valley of the Thames."* [See sketch map, Plate VII.]

Now the distribution of these materials has a most important bearing on the history of the Plateau Gravel bordering the valley of the Upper Thames, for it goes far towards proving that the formative agencies of the latter proceeded in the same direction, and, to a great extent, along much the same lines, as the existing drainage in the region involved. I shall deal with this point at a later stage of this paper. It is clear, however, from the foregoing remarks, that in discussing the origin of the doubtful deposits in the vicinity of the Thames, some account must be taken of the analogous drift phenomena presented by a more extensive area.

III.

As I have already stated, there is much diversity in the opinions expressed by different authors at various times with regard to the mode of formation of this high level, quartzite-bearing gravel. This want of agreement must, I think, be ascribed less to any abnormalities it exhibits than to the changing conceptions of geologists as a whole with respect to the relative importance and the capabilities of the various physical agencies of erosion, transportation, and deposition in operation in the past. Perhaps the best way to deal with the question will be to give a short *résumé* of the more relevant views put forward, and to state the objections to which they appear to be open.

* *Reliq. Diluv.*, p. 253.

Dr. Buckland* clearly recognised the closeness of the connection existing between the courses of the rivers Evenlode, Cherwell, and Thames, and the gravels with red quartzites, grits, etc.; and remarked that the occurrence of the latter on the plains and summits of the hills adjoining those streams tended to prove that their transportation and spreading out were accomplished, in the main, previously to the excavation of the valleys. He even went so far as to suggest that the transportation of the foreign débris and the excavation of the valleys was effected by one and the same agency. At a time when the powers of existing detritive agencies were greatly under-estimated, it is not surprising that even so keen an observer as Buckland should have found the facts of distribution and association inexplicable, except on assumption that a deluge had, at no very remote date, swept across the country from north to south, scattering the débris of one district over another, and then cutting out the valleys to nearly their present depth. Although the Deluge, as an agency of erosion and transportation, still has its supporters, it is hardly necessary, at this date, to point out the many serious objections which may be urged against the above explanation. Until the arguments of the modern supporters of the diluvian hypothesis assume a more tangible shape, geologists of the "orthodox" school may well be excused the labour involved in answering them.

Prof. Hull† regarded the quartzite-bearing gravel, and its associated sands and clays ("Northern Drift"), of the northern Cotteswolds as a marine formation belonging to the Glacial epoch, and attributed the transportation of the coarser material to the action of floating ice during a partial submergence of that district. The evidence brought forward lends little support to this view, however. There is nothing in the character or position of the older drifts of the area which can be said to point distinctly to a submergence such as Prof. Hull supposed. He admits that he had not succeeded in finding remains of marine organisms; but as the value of such negative evidence is small, it may be passed over.

The chief objection appears to lie in the limited distribution of the Northern Drift. Unless the submergence, during which these deposits are presumed to have been spread out, was of extremely local character, affecting a moderately small area of the Cotteswold country (which the amount of vertical displacement involved renders incredible), it is hard to see why the floating ice, which could drop part of its burden at elevations of over 700 feet O.D. near Stow-on-the-Wold and Chipping Norton, should have failed to scatter the remainder over a far wider area of the lower ground, to the south and south-east, than the deposits in question actually occupy. The tendency to follow the valleys

* *Op. cit.*

† *Op. cit.*

of the streams heading in the vale of Moreton manifested by the more important masses of this drift is quite at variance with the marine-glacial origin ascribed to them. This objection would, however, have seemed to have possessed little force to one who believed—as Prof. Hull then did—that all the valleys of the Cotteswolds were “entirely due to marine agency acting at several successive periods”;* and that the low-level deposits with mammalian remains of those valleys were estuarine!

Mr. Lucy, whose views with respect to the initial transporting agency operative in the case of the Northern Drift deposits of the Cotteswolds are very similar to those expressed by Prof. Hull, seeks to explain† their present restriction to the larger valleys and the heights adjacent thereto as the result of later glaciation by land ice, which, he thinks, swept the earlier marine drift down from the higher ground. But even though it be granted that land ice operated in the manner here suggested, we have still to account for the concentration of the drift (to which Mr. Lucy’s own map bears witness) in two or three of the many valleys which furrow the dip slope of the Lower Oolites in this region.

However, the evidence advanced in favour of such glaciation is extremely slight and indirect. Boulder Clay is absent; and the numerous sections of the gravelly drift described and figured by Mr. Lucy all exhibit the regular and orderly stratification and alternation of finer and coarser material which are so common a feature of the thicker deposits in this, and other, more eastern, portions of the Thames basin, and which are far more suggestive of the action of running water than of land ice.

In his well-known work, *The Geology of Oxford and the Valley of the Thames*, Prof. J. Phillips adopts a more cautious attitude than the authors whose opinions I have cited; and points out that the phenomena are not, on the whole, consistent with the marine origin advocated by them.

He considers that the “actual distribution” of the materials composing the high level gravelly drift (or “Hill Gravel”) near the valley of the Upper Thames, “is due to watery movement on the surface where they rest”; and remarks that “the sudden changes of level, and nature of the materials of these deposits in particular limited and especially high situations . . . give occasion for the opinion that something of ice action and currents, less continuous than ordinary streams, and less expanded than lake fluctuations or tidal swellings, must be called in to account for these facts.”‡

A more definite hypothesis is that advanced by the late Sir Joseph Prestwich, in that remarkable and suggestive series of papers “On the Relation of the Westleton Beds, etc., etc.,”§

* *Op. cit.* p. 484.

† *Op. cit.*

‡ P. 462.

§ *Quart. Journ. Geol. Soc.*, vol. xli (1890).

where he attributes the formation of this drift with the Triassic pebbles to the action of a "glacial current" trending from the direction of Warwickshire and Staffordshire. He, unfortunately, does not state the precise nature of the supposed current; but as he considers the resultant, and now isolated and widely separated deposits, such as those capping the Forest Marble and Great Oolite in the hills of Wychwood Forest, near Witney, the Coralline Oolite at Foxcombe and Wytham Hills, near Oxford, and the Chalk heights above Goring, to be the remains of a once continuous spread, laid down at a time when the intervening valleys were "bridged over by a flooring of Cretaceous and Jurassic Strata,"* we gather that the said current was not of such a kind, or of so late a date, as to necessitate the co-existence of *marine* conditions. It is, indeed, credited with erosive powers of a kind that we should ordinarily associate with a river, for to its agency Prestwich ascribes the initiation of the breach in the Chalk escarpment known as the "Goring Gorge." He is careful, however, to distinguish between the work of this glacial current and that of the River Thames, which, he thinks, did not occupy the gorge until a much later date: and his remarks on this important point require careful consideration. He states† that the River Thames must have been, at first, restricted to the Tertiary and Chalk basin "with the Kennet . . . as main stream and source of the river," and that the Upper Thames, or Isis, then probably flowed to the north-east, parallel to, and between, the Chalk and Oolite escarpments, and emptied itself into the Wash, on the east coast—the unification of the two drainage systems only taking place when the Goring Gorge, which had been commenced by the glacial current, had been cut out to such a depth by later glaciation, aided by disturbances of strata, as to induce the Isis to abandon its older course and to effect a junction with the Kennet-Thames.

This suggestion, which has always seemed to me to be somewhat extravagant, is open to other serious objections.

In the first place, there is very good reason to think that the north-western glacial current, or the agency distinguished by that name, whose field of operations was a restricted one, followed some existing depression when it crossed the outcrop of the Chalk. Whatever its nature, and however slightly defined, this depression must still have been deeper and more pronounced than any other in the neighbourhood; for it is unlikely that the said current would have followed it had an easier route lain open. Supposing such a valley to have existed, it is extremely hard to see why the Isis should not at once have taken advantage of the channel resulting from its deeper erosion by the glacial current.

Then, if the basins of the Isis and the Kennet-Thames were

* *Op. cit.*, part ii., p. 150.

† *Ibid.*, p. 177.

indeed originally separate and distinct, it is difficult, with the physiographical features of the district in view, to see in what way they could have ever become united. Prestwich's suggested explanation, that the effectual breaching of the Chalk escarpment was due to "later glaciation" (as distinguished from the work of the earlier glacial current), and earth movements is, at best, unsatisfactory. What form of glaciation was it that carved out that steepest 220 feet* of the Goring Gorge? This narrow breach cannot be attributed to lateral erosion of the Isis; nor can we reasonably suppose it to have been formed by the recession of the head springs of some tributary of the Kennet; for, even though we accept the doubtful principle involved in the latter alternative (viz., that of escarpment-breaching by the headward erosion of a stream following the dip slope),† it is inconceivable that so short and insignificant a stream, as this must necessarily have been, could have cut back its valley through the Chalk ridge of the watershed so rapidly as to cause the diversion of the stronger Isis, which had established its course to the sea along the outcrop of the easily eroded beds of Upper Jurassic and Cretaceous age.

Moreover, as Dr. J. W. Gregory has pointed out,‡ such evidence as we possess is opposed to the view that the Upper Thames, or Isis, ever flowed north-eastward, up the longitudinal valley of the south-westward flowing Thame, across the watershed, and down the Ouse into the Wash. The great irregularity and sinuous course of the Thame-Ouse watershed "renders it very improbable that it could have been formed by a line of elevation which broke across the former course of a river. Further, the only way in which the Thame could have surmounted the barrier would have been by its waters having stood at a higher level; there is no evidence of any great lake which discharged to the north, or of movements of the country which have since lowered the valley of the Thame."§

It seems much simpler and more consistent to regard the Goring Gorge, as Dr. Gregory does, as one of the series of parallel, transverse, north-west to south-east valleys—such as those of the rivers Loudwater, Misbourn, Bulbourne and Lea—intersecting the Chilterns, which have been formed by the streams occupying them at the present time.||

The authors of most of the later works dealing directly with the high-level quartzose gravel, and associated sands, in the neighbourhood of the Thames have been content to regard such

* *Op. cit.*, p. 149, diagram.

† "Il paraît en effet impossible d'admettre, et cette observation est general, qu'un cours d'eau qui se forme sur une pente terminée par un escarpment puisse prolonger sa vallée jusqu'à sa rencontre avec la crête, parce que, au fur et à mesure qu'il s'en rapproche, la surface qui l'alimente diminue et se réduit à zéro dans la voisinage de la crête." J. de la Noë and E. de Margerie, in *Les Formes du Terrain* (1888), p. 136.

‡ "The Evolution of the Thames," *Natural Science*, vol. v, August, 1894, p. 97.

§ *Ibid.*, p. 103.

|| *Vide also* Whitaker, "Report of Excursion to Goring," May 25th, 1895, *Proc. Geol. Assoc.*, vol. xiv, p. 175.

deposits as Glacial (more or less in Mr. Whitaker's sense of the term) without raising any question as to their mode of formation; but while their resemblance to the river drifts, and the difficulty of separating them from the latter, have been remarked by Mr. Whitaker,* as I have already mentioned, by Messrs. H. B. Woodward,† Monckton,‡ Shrubsole,§ and, rather to the east of our district, by Mr. Allen Brown,|| there has been, I think, a general tendency to look upon them as marine, or as the remodelled relics of a marine formation—a view suggested by the wide extent of ground they cover, and by the apparent closeness of their relation to the Middle Glacial Gravels of East Anglia, which have yielded marine mollusca.

Speaking of the Glacial Gravel of the north-western Chilterns, Dr. Gregory, in his very instructive paper on "The Evolution of the Thames," remarks: "There is no Boulder Clay in this immediate district, but the gravels, though somewhat different in composition, appear to be continuous with those which pass under this deposit further east. They are, therefore, earlier than the Boulder Clay. Though marked" [on the Geological Survey Map, Sheets 7 and 13] "as 'Glacial,' no one would be likely to maintain that they are glacial in the same sense as is the Boulder Clay. They are certainly due to water action in some form, instead of to the direct agency of ice like a moraine."¶ Dr. Gregory is inclined to believe that these gravels, which he distinguishes as "Newer Plateau Gravels," were spread out on a plain of denudation; but the frequent rapid variations of level exhibited by the component masses seem to show that they could never have been united in one practically continuous sheet.

In a paper "On the Distribution and Relations of the Westleton and Glacial Gravels in Parts of Oxfordshire and Berkshire,"** read before this Association in 1894, I remarked that the drift phenomena of the country bordering the Thames between Streatley and Cookham seemed to me "to point very distinctly to the conclusion that, whatever may have been the conditions under which the red quartzites and other foreign rocks were introduced into this area, the spreading out of the product of their mixture with local materials—which is known as the 'Glacial Gravel'—was accomplished by fluvial agency,"†† and I endeavoured to show that the evidence was, on the whole, strongly in favour of the view that the plateau-like deposits of that drift occurring on both sides of the Thames, are terraces formed by that river during the early stages of valley excavation.

* *Op. cit.*, pp. 300, 301.

† *The Geology of England and Wales* (Ed. 2nd), p. 506.

‡ *Op. cit.*, p. 324.

§ "On the Valley Gravels about Reading," *Quart. Journ. Geol. Soc.*, vol. xlii, p. 582.

|| "On the High Level River Drift between Hanwell and Iver," *Proc. Geol. Assoc.*, vol. xiv, p. 153.

¶ *P.* 101.

** *Proc. Geol. Assoc.*, vol. xiv, Part I.

†† *P.* 27.

The limited scope of my paper, and a want of personal acquaintance with the gravels farther west, prevented me from suggesting that the similar deposits in corresponding situations near Oxford, and other localities higher up the Thames Valley, had been formed in the same manner, though I saw that this would be the logical sequel to the views I had expressed. Sharing, moreover, the prevalent opinion (supported by Dr. Gregory in the work I have referred to above*) that the drainage system of the Upper Thames had always been confined, as it now is, to terrains of Jurassic and later age, I felt great difficulty in accounting for the presence therein of Triassic débris by any purely fluvial hypothesis. The operation of some other agency seemed to be required to effect its transportation across the western watershed in the first instance.

IV.

Much light, however, has been indirectly thrown upon this problem by Prof. W. M. Davis, of Harvard University, in his admirable paper on "The Development of Certain English Rivers," published in the fifth volume of *The Geographical Journal* (1895). In this work—distinguished for its acumen, its suggestiveness, and for the valuable comprehensive technical terms it introduces—the author shows how the application of certain principles of river adjustment, which seem to have met with more general recognition on the Continent and in the United States than in our islands, leads one to form most interesting and important conclusions touching the history and relations of the streams draining the Midland and Eastern counties of England. In the case of the Thames, the conclusions reached have such an important bearing on the subject under discussion that it is necessary to give some account of them here. To this end I proceed to quote some of Prof. Davis' remarks :

"Of all the river contests in England, that by which the Thames system has been shorn of its original importance is the most interesting. . . . [The Severn] gathers a great drainage from Wales that used to go to the western branches of the Thames system ; the Warwick Avon still further shortens these branches ; while the Trent and the Bedford Ouse carry away the heads of many original northern branches. Only the southern branches of the Thames, draining the northern slope of the dome of the Weald, retain anything like their original extension.

The longitudinal axis of the Thames system, following an eastward-dipping synclinal trough, now heads in the Kennet by Marlborough. . . . Running generally south-eastward into this trough, from the slope on its northern side, there should be, if no adjustments had taken place, a number of long consequent streams, heading at least as far westward as the Mesozoic strata

* *Natural Science*, vol. v, August, 1894.

stretched, and possibly rising in extended streams from such parts of the Welsh highlands as were not submerged and buried by the Chalk. There is much probability that such streams once existed; but now nearly all of them have been broken into three parts by the growth of subsequent streams along the New Red and the Middle Oolite. . . . The Thames from Reading to Oxford, and the Cherwell or the Evenlode above Oxford, makes the longest remaining part of an initial consequent stream; and it is interesting to notice that these two upper streams still drain a moderate area of Lias country beyond the Oolitic upland, and between the competing headwaters of the subsequent Warwick Avon on the west, Bedford Ouse on the east, and Trent on the north. This is precisely the region where the longest remaining parts of the initial consequent streams should be expected; . . . Whether the upper Severn represents the original head-stream of the Cherwell or of the Evenlode is a matter for speculation rather than for demonstration. South-east of the Oolite margin, the upper Ray on the east of Oxford, and the Windrush, Coln, Churn, and Swill on the west, are short medial parts of consequent streams which have lost their heads by the successful growth of the Ouse and the Avon. . . .”*

The justice of Professor Davis' conclusions, and the soundness of the premises on which they are based will, I think, be apparent to all who study his remarkable paper.

The admission that the Thames originally received the drainage of a large area of country in the north-west, whose waters now accrue to the Severn, Ouse, and Avon, not only removes the initial difficulty of accounting for the introduction of the Triassic debris, but also furnishes, as I hope to show, an extremely simple and consistent explanation of the structure and distribution of the high-level gravels of which that debris forms so important a constituent.

Professor Davis starts with the assumption that the eastward-flowing English rivers have developed from streams draining a south-eastward sloping plain of denudation, whose formation he is inclined to ascribe to sub-aerial agencies operating during an earlier cycle of river development, rather than to the horizontal abrasion of the sea, favoured by the British school of physiographers.† While admitting the ability of the atmospheric agencies to produce a plain (or *peneplain*) of denudation as “the ultimate result of the valley-making process,” I am not convinced that the physiography of south-eastern England is such as to compel us to assume that the elevated plain (lowland), out of which the present diversity of hill and vale have been carved, was formed in this manner. The plateau-like uplands of the Oolite and the

* Pp. 144 and 145.

† For a comparison of the views of British and foreign authors with regard to the formation of plains of denudation, *vide* W. M. Davis on “Plains of Marine and Sub-aerial Denudation.” *Bull. Geol. Soc. America*, vol. vii.

Chalk, which Professor Davis regards as the remnants of the *peneplain*, are, so far as I have seen, destitute of all traces of the wide-spread sheets of water-worn detritus in which an area so broadly levelled must assuredly be enveloped. The patches of Westley Shingle occurring on the Chiltern Hills, at a general level somewhat lower than that of the crest-line of this range, and traceable as far west as Kingsdown, near Bath,* are the only deposits which could possibly be referred to this stage; but both the stratigraphical affinities and the general aspect of this pebbly deposit proclaim its origin to be marine. This, however, is a question which need not be gone into here.

Whatever the origin of this plain of denudation, there can be but little doubt that the Mesozoic strata had been subjected to a considerable amount of destruction in the west before the inception of the existing main lines of N.W. to S.E. drainage. We have abundant evidence of this in the position and composition of beds dating as far back as the Eocene period.† How far the work of denudation had proceeded we cannot say with any approach to exactitude, but it seems not unreasonable to infer that, while the Chalk and its superincumbent beds may have formed the greater part‡ of the floor of the plain, the lower members of the Secondary group were exposed to a considerable extent in the west. In this case, the earliest "consequent" streams—such as those represented by the existing Evenlode and Cherwell—rising in the Welsh highlands, and running thence south-eastward, with the dip of the Secondary rocks, must have traversed the outcrops of all the denuded strata in succession, from the oldest upward, carrying the débris of the earlier beds on to the later; so that, even in the earliest stage, the alluvium occurring in the beds of such streams, at so great a distance from their sources, must have been of mixed character.

In the course of time, the initial streams, whose individual courses were determined by such irregularities and deflections of surface as existed in the plain of denudation, eroded valleys of suitable proportions, thereby giving rise to a second set of streams tributary to the first, and running at approximately right angles thereto, *i.e.*, parallel to the strike of the underlying rocks. With the deepening of the valleys of the primary transverse, or consequent streams, the secondary longitudinal, or "subsequent" streams first insignificant, increased in importance, the development being most rapid in the case (1) of those following the outcrop of soft and easily eroded beds as the Trias, Lias, and the Oxford clays, and (2) of those feeding the stronger consequent streams. By the quicker destruction, in this manner, of the weaker strata

* Prestwich, *Quart. Journ. Geol. Soc.*, vol. xlv, p. 143.

† Clement Reid on "The Eocene Deposits of Dorset," *Quart. Journ. Geol. Soc.*, vol. lii.

‡ Ramsay thinks "the whole." *Vide* his *Physical Geology and Geography of Great Britain*, sixth edition (1894), p. 358; and *Quart. Journ. Geol. Soc.*, vol. xxviii (1872), p. 143.

the **Outcropping** edges of the stronger (*e.g.*, the Oolite Limestones and the Chalk) were gradually developed into more or less marked **escarpments**, which were cut back in the direction of the dip at **rates** largely dependent on the amount of resistance they were able to offer to the sub-aerial agencies.* The recession of the **escarpments** must necessarily have resulted in the destruction of **much** of the earliest deposits of alluvium spared by the more **direct** processes of detrition.

By-and-by, the more rapid development of the subsequent streams feeding the stronger consequents led them to encroach, by headward erosion, upon the drainage area of those attached to the neighbouring weaker consequents, and eventually to decapitate the weaker consequents themselves. By adjustments of this kind, taking place along the outcrop of the easily eroded Trias and Lower Lias, the headwaters of the Evenlode, Cherwell, and possibly also of the Windrush, and other, lesser, north-western tributaries of the Thames, were diverted, and the importance of the drainage system of the last-named river proportionately reduced; the Warwick Avon, and another subsequent stream now forming the lower part of the Severn, cutting off practically the whole of the drainage of the country lying to the west of the Oolite escarpment of the Cotteswold Hills.† With the beheading of the above-mentioned important consequent or transverse streams, the supply of débris from rocks of earlier age than the Lias, which they had hitherto furnished, came to an end. And the volume of water in these branch streams, and, therefore, also in the main or trunk stream, being greatly reduced, the width of the channels they were thereafter able to erode was correspondingly diminished. Of later changes and adjustments it is not necessary to speak.

Now we have seen that the high-level quartzose gravel, and its associated finer drifts, bordering the Thames Valley follow the courses of the rivers Cherwell, Evenlode, and, to a less extent, of the Windrush, spreading along the higher slopes of, and less inclined plateaux adjacent to their valleys, from their junction with the main stream near Oxford, through deep gaps in the Oolite escarpment, up to and beyond their sources on the Lias. This distribution is, in itself, strongly suggestive of some fundamental connection with these rivers and their valleys—leading, as we have seen, a keen observer‡ in the pre-Uniformitarian days to speculate on the probability of both gravel and valleys being the work of the same forces. Its full significance, however, becomes apparent only when we learn—by a wholly independent course of reasoning—that the Cherwell, Evenlode, and Windrush are precisely those

* *Vide* C. le Neve Foster and W. Topley "On the Superficial Deposits of the Medway, etc." *Quart. Journ. Geol. Soc.*, vol. xxi (1865), p. 471.

† The principle here involved is that which Mr. Jukes-Browne seeks to establish in his paper "On the Relative Ages of Certain River Valleys in Lincolnshire," *Quart. Journ. Geol. Soc.*, vol xxxix (1883), p. 598.

‡ Dr. Buckland.

transverse consequent streams which originally drained a large tract of country where the parent rocks of the quartzites and grits are now, and have long been, exposed at the surface; and in whose early alluvium we should, therefore, expect such materials to occur. Regarded in this light, the occurrence of Triassic débris in and near to the valleys of these north-western affluents of the Thames is seen to be perfectly analogous to that of the similar materials in the gravels which border the River Witham to the east of Lincoln;* or to that of the Lower Greensand chert in the dry, beheaded valley of Smitham Bottom, which breaches the North Downs† south of Croydon.

There are other important facts which tend to confirm the view that the high-level gravel with Triassic débris of the upper part of the Thames basin was formed by its associated streams, at earlier stages of their development. For example, we find that, like those streams, the gravel attains its greatest elevation in the north-west, and falls away south-eastward, in the direction of the dip of the underlying rocks, so that its highest deposits on the Inferior Oolite of the Cotteswolds are at a greater distance above sea-level than those capping the great Oolite of Wychwood Forest, and these, in turn, higher than those forming the highest terrace on the Chalk of the Chilterns. Had the drift been of more wide-spread occurrence the confirmatory value of this fact would have been small; but in view of its limited distribution, the coincidence has considerable weight.

We notice, too, that where the streams intersect the bold escarpments, and their valleys are most steep and contracted, the gravel is likewise confined within narrower and sharper limits than elsewhere—this feature being particularly well-marked in the case of the Chalk escarpment, near Goring.

Then, the highest deposits in any given portion of the whole area are commonly found just within such escarpments; which is precisely the place where we should look for the oldest river deposits.‡

The quartzites and other foreign rock-fragments, also, are larger and more abundant in the west than in the east, and in the plateau deposits of the higher and gentler slopes than in the terraces on the lower, steeper slopes of the valleys; as they should be if their transportation had been effected in the manner suggested—the diminution in size and numbers to the eastward and towards lower levels, being the complement of their increasing distance from their source, in the former case, and of the cessation of supply consequent on changes in the drainage, in the latter.

* A. J. Jukes-Browne, *op. cit.*, p. 608.

† Prestwich, *op. cit.*, pp. 171-173.

‡ I am inclined to regard the pebbly deposit of mixed character capping the Tertiary outlier of Streatley Hill (550 O.D.), on the west side of the Goring Gorge, as a relic of the oldest river terrace of the district. Vide *Proc. Geol. Assoc.*, vol. xiv, Part I, pp. 21, 22.

When, in addition to these facts, we call to mind the stratified character of this gravel, its frequent association with sands and loam, and its occurrence in the form of plateau-like terraces at varying levels—the lower being often inseparable from the deposits which are admitted to belong to the River Drift—it seems almost impossible to resist the conclusion that, despite the great elevation it attains above the beds of the neighbouring streams, this gravel owes its existence to fluvial agency operating along the same general lines of drainage as those in existence at the present day.

Taken collectively, the facts do not appear to admit of any other reasonable explanation. The distribution, mode of occurrence, and structure of this high-level gravel certainly do not warrant the assumption that it is, in any sense, a marine deposit: for now can we reconcile such a mode of formation with (1) its close association with the transverse valleys of the consequent streams and its disregard for the wider, longitudinal valleys of the subsequent streams; (2) its occurrence in impersistent terraces at rapidly varying heights; and (3) the angular condition of a large proportion of its component rock fragments?

It may be urged that this plateau-forming drift is merely the sub-aerially remodelled detritus of an older marine formation; but, apart from other objections, when we bear in mind the distribution and structure of its component masses it is obvious that this view involves the operation of sub-aerial agencies from such an early stage as to justify us in doubting the necessity for supposing the drift to have been a marine deposit in the first instance.

There is no reason to think that the part played by ice in the formation of this gravel was ever more than a subordinate one.

The rejection of the marine hypothesis involves that of the transportation by icebergs, which was favoured by the earlier writers on the subject; and of the action of land ice, on an important scale, there is no definite sign. The only feature exhibited by the drifts of the region with which this paper is particularly concerned which really seems to call for ice action, is that of the larger masses of grit, marlstone, oolite,* etc., occurring in the valleys, and which, as Professor Phillips remarked,† would otherwise require a current of a strength and velocity only to be found in an Alpine river. As such boulders, however, are especially characteristic of the low-level deposits, whose fluvial origin is universally acknowledged, their transportation may, with some show of probability, be ascribed to a form of glaciation operative, in a moderate degree, in this country during the present age,‡ viz. river ice.

* Buckland, Hull, and Lucy, *op. cit.*; and Prestwich, *Quar. Journ. Geol. Soc.*, vol. xii, p. 132.

† *Op. cit.*, p. 463.

‡ At the breaking up of the severe frost of January and February, 1895, I witnessed, on the foreshore at Gravesend, the rooting up and removal by floating ice of blocks of chalk and unworn flint nodules upwards of one foot in diameter.

V.

I cannot here attempt to discuss the question as to the relation of the High-Level Gravel bordering the valley of the Upper Thames to the, in many respects, closely similar "Glacial" deposits which cover such wide areas in the north-eastern districts of the London Basin. In country of low relief, such as is found in the counties of Essex and Suffolk, where many diverse agencies have been at work over a long period on practically the same floor, it is not easy to distinguish between the effects of those agencies, particularly when they happen to be, to a large extent, of the glacial order. Nevertheless, I venture to think that, when due allowance is made for complications arising from such causes, these north-eastern spreads of gravelly drift will be found to admit of an explanation similar to that which I have advanced with respect to those occurring between Moreton-in-the-Marsh and Banbury, on the one hand, and the Maidenhead District, on the other.

Of course, I do not mean to imply that the Thames itself is responsible for the masses of gravel and sand which extend along the Tertiary escarpment by Rickmansworth and Hatfield, into Essex. Both the composition of these masses and their relations to the drainage systems of that district seem to point to their constituents having been introduced, in the first instance, by an independent stream flowing from the Midlands into the synclinal trough of the London Basin through some channel corresponding to, but lying at a considerable distance to the north-east of, the Goring Gorge—a possibility suggested to me some two years ago by Mr. Jukes-Browne. More recently, Mr. A. E. Salter has called attention * to the connection existing between the gaps in the Chalk escarpment of the Chiltern Hills and the contiguous deposits of drift; and it is to be hoped that we may, ere long, be in possession of facts which will enable us to test the value of this hypothesis.

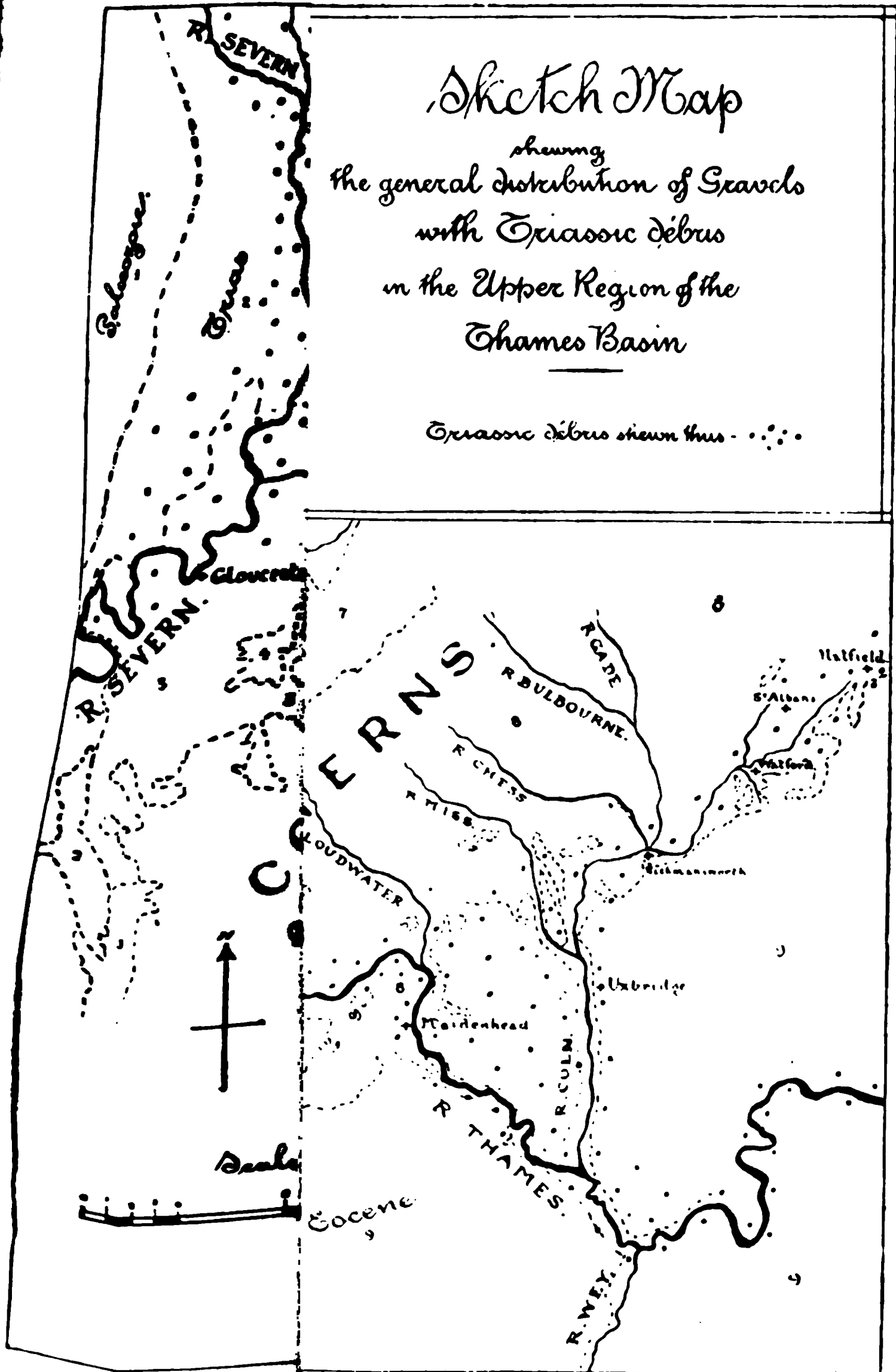
The whole subject of the transported rock fragments in the drifts of Southern England is full of interest, and much work remains to be done in the direction of tracing the routes, and determining the nature of the agencies, by which these materials have been carried into their present positions. I shall be well satisfied if this paper serves but to awaken a more active interest in this important, though somewhat neglected, branch of geological inquiry.

* "‘Pebbly Gravel’ from Goring Gap to the Norfolk Coast," *Proc. Geol. Assn.* vol. xiv, p. 329; also Note on "Excursion to Hitchin," p. 419.

Sketch Map

showing
the general distribution of Gravels
with Triassic debris
in the Upper Region of the
Thames Basin

Triassic debris shown thus -



H. J. Osborne White.

CURSION TO CHELTENHAM AND STROUD.

WHITSUNTIDE, 1897.

tors : E. WETHERED, F.G.S., AND S. S. BUCKMAN, F.G.S.*Excursion Secretary* : R. S. HERRIES, M.A., SEC. G.S.*(Report by S. S. BUCKMAN.)*

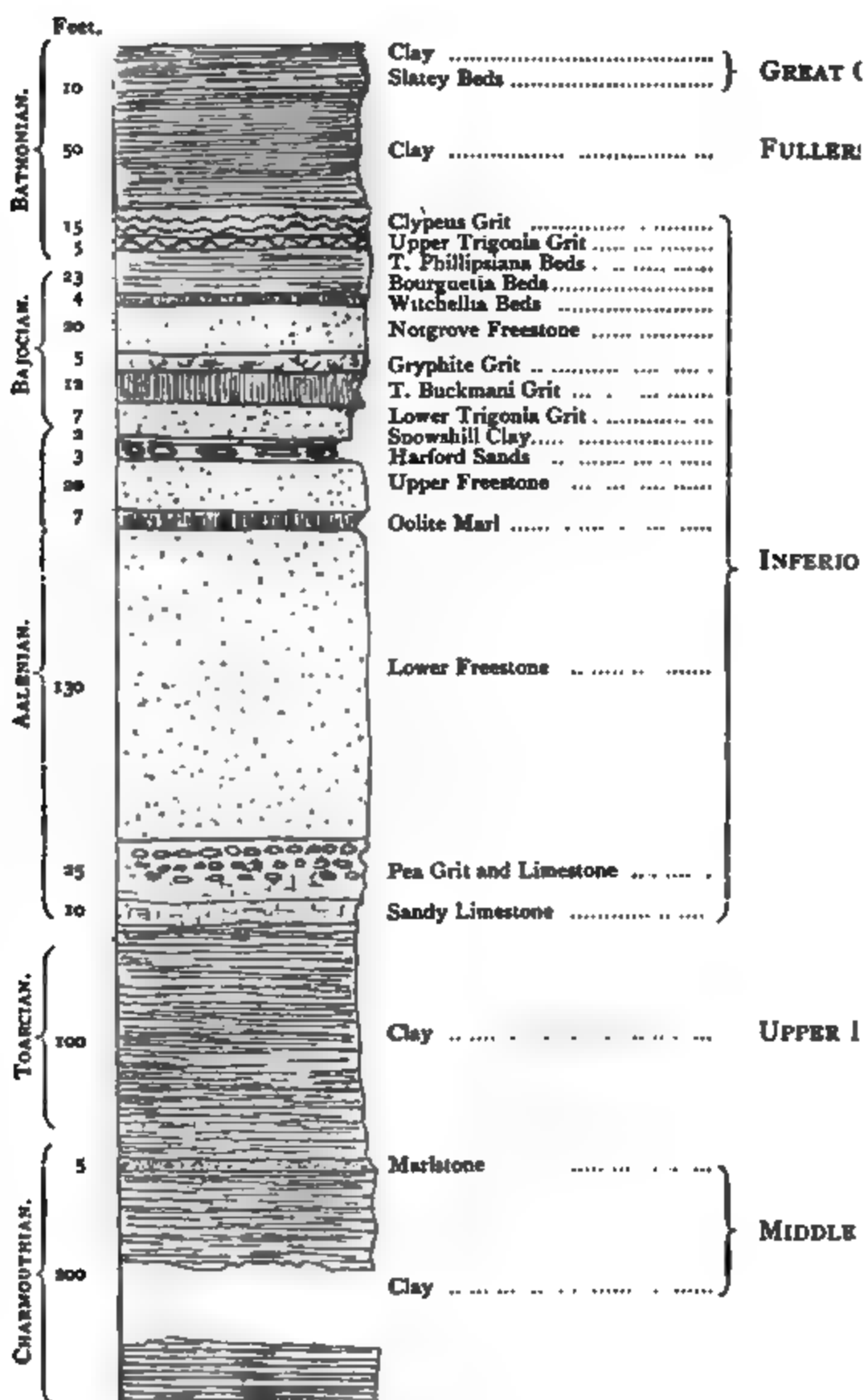
main body of the party travelled from Paddington to Cheltenham by the 10.32 a.m. train on Saturday, June 5th, and took up their quarters at the "Plough Hotel." On arrival at Cheltenham they were met by the Directors, and at once proceeded to Leckhampton Hill.

The object of the excursion was to investigate the portion of the Cotteswold deposits exposed to view from the foot to the top of the Cotteswold Hills, in the environs of the towns of Cheltenham and Stroud. The beds which may thus be seen range from the Lower Lias up to the Great Oolite; and an approximative diagram (Fig. 1) of their sequence in the neighbourhood of the town is given.

The town of Cheltenham lies in the valley of the Severn, and is bordered on the east and south by the Cotteswold Hills. The hills form very striking features of the landscape because of their abruptness with some considerable abruptness from the valley. It is by the excavation of the Severn Valley that these hills have been formed, by the removal in this process of the westward continuation of the same strata of which the hills are composed. The excavation has had a definite effect upon the contour of the hills, according to the different degrees of hardness of the strata superimposed on one another. There is, as the most striking feature, a prominent, bold escarpment, due to a very considerable thickness of limestone rocks; but this bold escarpment is more or less interrupted by a subsidiary escarpment some distance above the line of the valley, and again it is in places topped by a third escarpment. So that the appearance presented by the Cotteswold Hills overhanging the Severn Valley is at first sight a prominent cliff; but upon nearer inspection two, and sometimes three, unequal step-like cliffs. The annexed sketch (Fig. 2) illustrates these features, which have, of course, intimate connection with the scenery.

Further modification of the Cotteswold scenery is produced by the alternation of limestone and clay. The clays being the softer strata, it is from the top of them that the water falling on the superjacent limestones is thrown off; and this in the shape of streams, has cut valleys at right angles to the Cotteswold escarpment to bring the drainage into the Severn. In this way the general western face of the Cotteswold Hills is

* Lower Lias of Geological Survey, in part.



Scale, 1 inch = 100 feet. Thickness of beds approximate.

FIG. 1.—SEQUENCE OF STRATA IN THE CHELTENHAM DISTRICT.—S. S

interrupted at certain points, producing north and south faces overlooking lateral valleys tributary to the main Severn valley. The valley of the Chelt, the river whereon Cheltenham is situated, and the valley of the Frome, in which Stroud stands, are both of them such lateral valleys, holding streams tributary to the Severn. But such valleys are not numerous; and, consequently, there is not so much interruption to the regular line of the Cotteswold western escarpment as might have been expected. This is due to the fact that the beds of the Cotteswold Hills have a slight S.E. dip, so that there is an inducement for the drainage to flow in a south-easterly direction. And such is the case—the main drainage of the Cotteswold area finds its way into the more distant Thames, and not into the nearer Severn, as it might

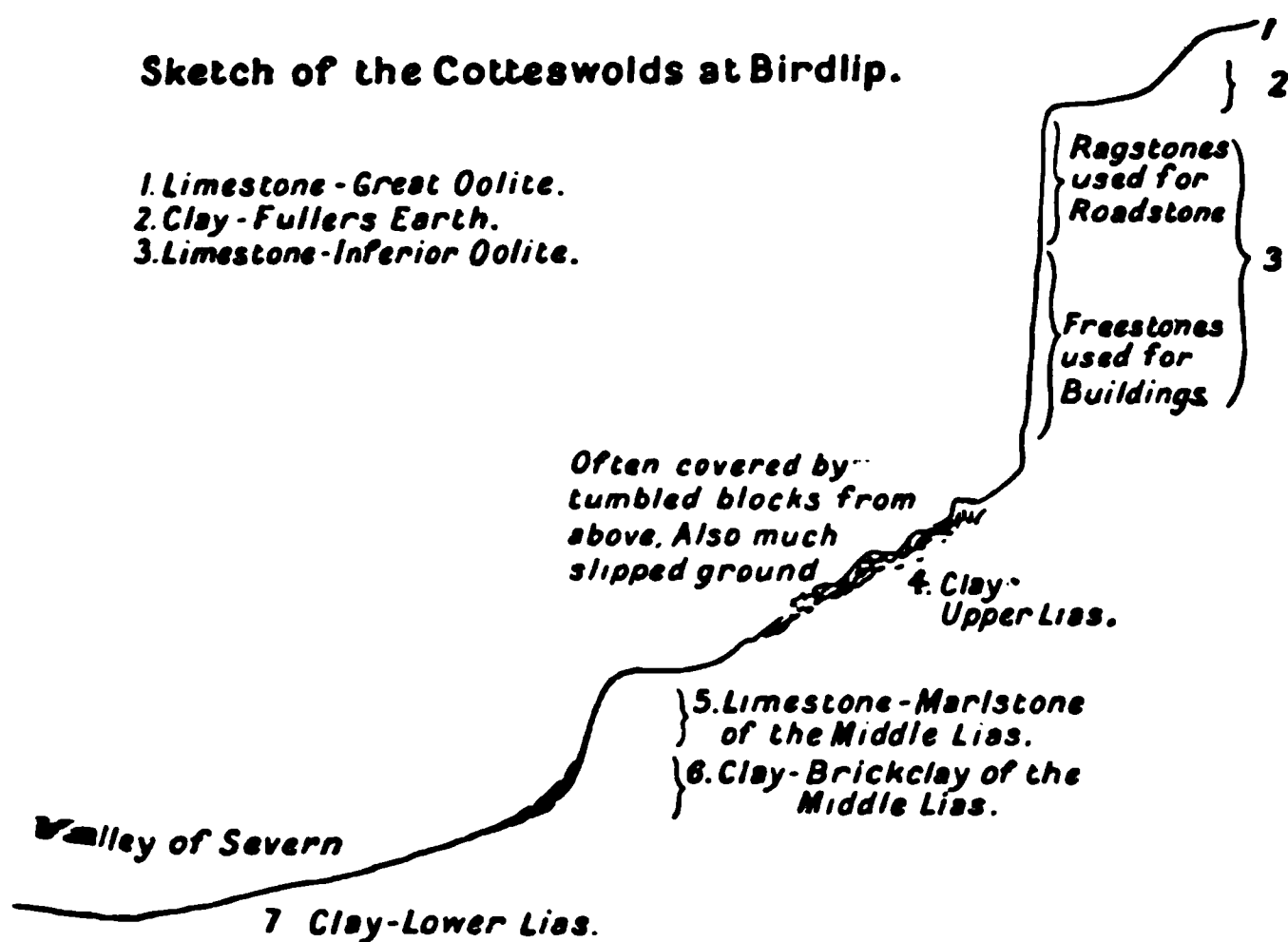
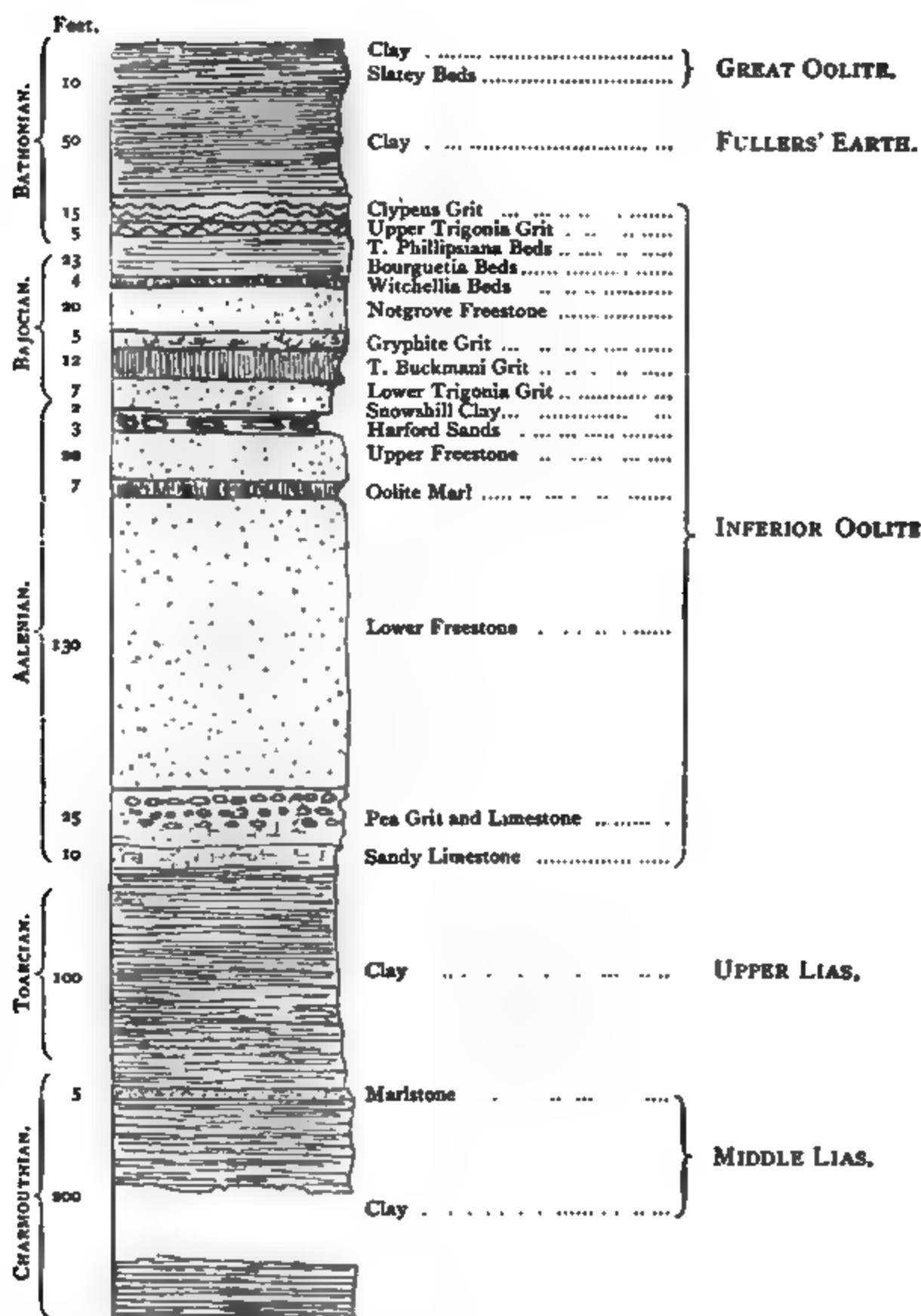


FIG. 2.

have done but for this dip. Consequently the Cotteswold escarpment is more continuous and less interrupted than it might otherwise have been, and therefore the scenery partakes of somewhat the same character for a very considerable distance. Such are the general characters of the physiography of the district which the members proceeded to examine in detail.

From the station the party proceeded across a gradual rise over Middle Lias strata towards Leckhampton Hill (Fig. 3). At Leckhampton Station a brickyard was visited, showing a section of clay beds of the Middle Lias, yielding Ammonites of the genus *Cycloceras* (*Valdani*-group), mostly somewhat thick-whorled forms allied to *Cycl. subarietiforme*, Futterer, also species allied to, or identical with, *Cycl. flandrini* (Dumortier), and *Cycl. valdani* (d'Orb.). Also there were *Lytoceratites*, as *Phylloceras loscombi*



Scale, 1 inch = 100 feet. Thickness of beds approximate.

FIG. 1.—SEQUENCE OF STRATA IN THE CHELTENHAM DISTRICT.—S. S. Buckman

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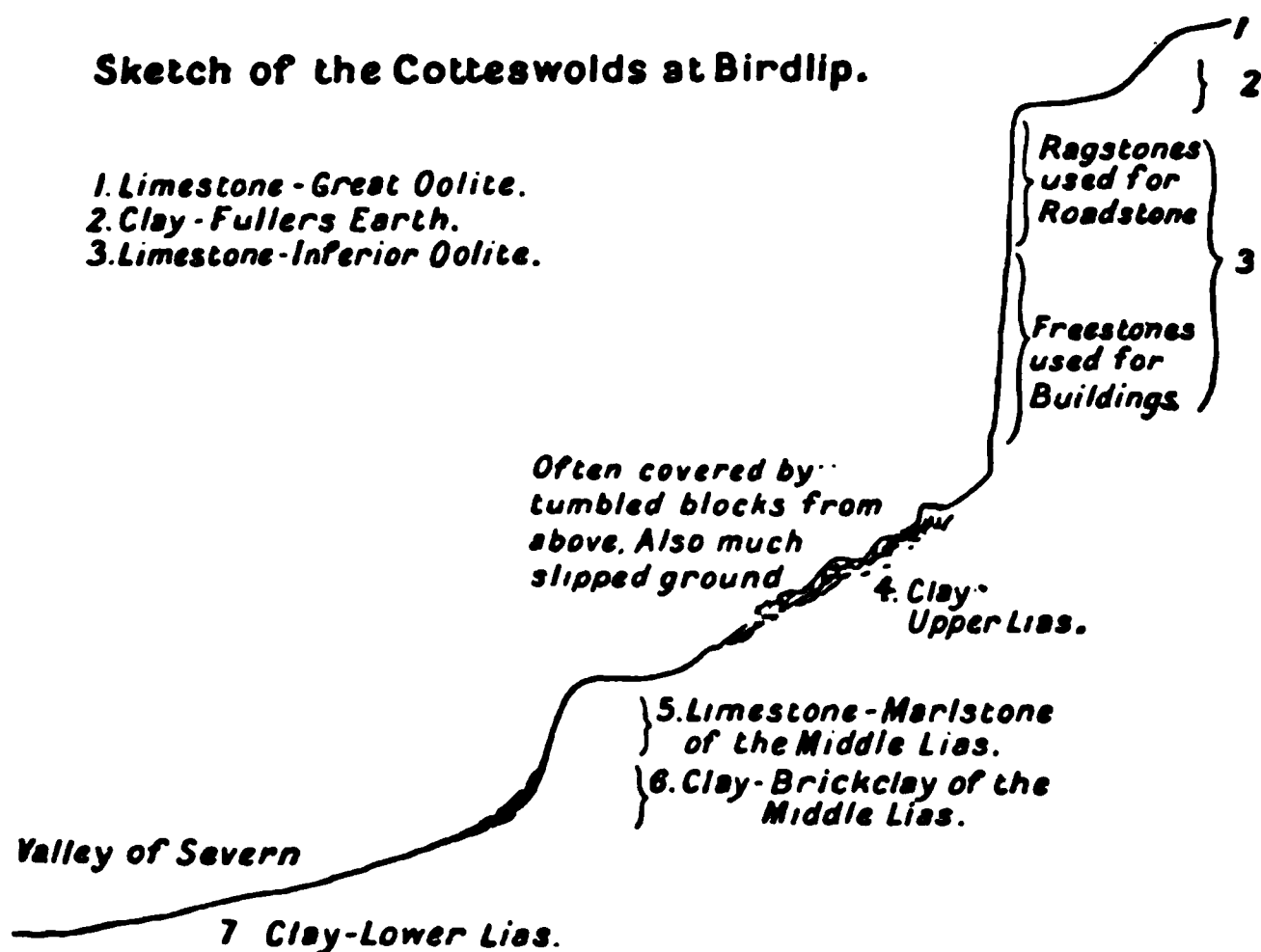


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(Sow.). So that the horizon was known to be that called "Zone of *valdani*" (sometimes "zone of *ibex*") in the Middle (or, as the Geological Survey have it, Lower) Lias, about two zones below the "*spinatus* zone" at the top of the Marlstone of the Middle* Lias.†

Farther up the hill Pilley Brickyard was visited. The succession of Ammonites was shown by the fact that species of *Liparoceras* were found in this section; *Liparoceras striatum* (Reinecke), and *Lip. latacostatum* (Sow.)‡ were obtained by the members. A varied series of bivalves was also to be found.

The party then ascended the hill, passing up the subsidiary escarpment to the plateau of the Marlstone (top of *c*, Fig. 3), and up the slope of the Upper Lias (*d*, Fig. 3) to the large cliff-like working by the Middle Gin (lower part of *c*, Fig. 3). Here is presented to view in a large quarry:

Upper Freestone.

Oolite Marl.

Lower Freestone.

Pea Grit. §

The fossiliferous beds are the Pea Grit and the Oolite Marl, while the massive Freestones are of greater economical interest as building stones. The Pea Grit, however, is used for rougher work, and is chipped into shape—it cannot be sawn.

After Mr. Wethered had given a general sketch of the geology of the district, and pointed out as many features of the view as the hazy weather would permit, the members proceeded to explore the fossiliferous beds, viz., the Pea Grit near the Middle Gin and the Oolite Marl, at a more accessible spot above the Devil's Chimney, on the western side of the hill.

The Devil's Chimney is an isolated pillar of rock, long thought to be due to natural denuding agencies. Its initiation may be attributed to a fault of about 18 inches, producing a downthrow and a separation from the main mass of the hill. The frost then attacked the main mass of the hill more than the pillar, because the main mass would always retain more natural moisture. So a certain amount of separation was commenced; but it seems, from evidence now available, that quarrymen are responsible for the greater separation seen at the present day, by having cut a passage for a tramroad to take stone from the hill-top.

The party then walked over the hill, noticing the old camp. Next they investigated the beds of Ragstone, a term generally used to designate the strata above the Upper Freestone. In

* In Fig. 3 "Lower Lias."

† Reference to tables of Ammonite zones contained in the works of Oppel (Jura-formation), Tate and Blake (Yorkshire Lias), Wright (Lias Ammonites), Buckman (Inferior Oolite Ammonites) will show the point reached, and will enable the reader to follow the upward sequence. The latest table—the fullest in connection with the horizons above *spinatus*—is given by Buckman and Wilson, Dundry Hill, *Quart. Journ. Geol. Soc.*, vol lii, table iv.

‡ Generally but incorrectly known by names proper to other species, viz., as "*henleyi*" and "*capricornus*" respectively.

§ See the Table of Sequence of Strata, Fig. 1.

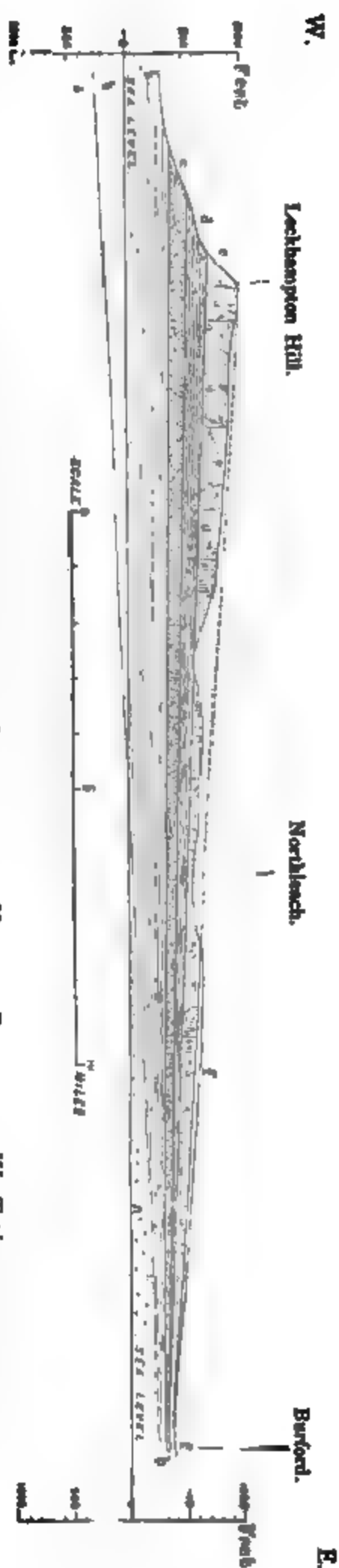


FIG. 3.—DIAGRAM-SECTION FROM LECKHAMPTON HILL TO BURFORD.—W. Topley.

b. Lower Lias.
a. Keuper Marl, etc.

d. Upper Lias.
c. Middle Lias.

f. Great Oolite Series.
e. Inferior Oolite Series.

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FIG. 4.—DIAGRAM-SECTION FROM STROUD TO CIRENCESTER.—H. B. Woodward.

3. Upper Lias.
2. Middle Lias.
1. Lower Lias.

6. Fuller's Earth (Fullonian).
5. Inferior Oolite.
4. Cottanwold Sands.

9. Cornbrash.
8. Forest Marble.
7. Great Oolite.

(Length about 15 miles.)

reference to the succession of the Ragstone beds, Mr. Buckman pointed out that at Leckhampton Hill the Upper *Trigonia*-grit rests upon a few feet of Notgrove Freestone; that in going southwards towards Birdlip the former bed is found to rest successively upon the different rocks from Notgrove Freestone to Upper Freestone;* but that northwards more strata intervened, as he would have an opportunity to show at Cleeve Hill.

Returning down the hillside the members found that Mr. Dale, of Daisybank, the owner of Leckhampton Hill, had very considerately opened for them a capital section in the Oolite Marl, and this being in a virgin condition yielded excellent results. The same gentleman also kindly provided refreshment for the party at his house, which the oppressive heat of the day made most welcome; and the return was then made to Cheltenham.

[Several of the members visited Mr. and Mrs. Buckman, at Charlton Kings, and after tea on the lawn they inspected Mr. Buckman's fine collection of fossils. Much admiration was expressed at the beautiful preservation of the Cephalopoda and Brachiopoda exhibited.—R.S.H.]

On Monday, June 7th, the members walked to Charlton Kings, and examined a gravel pit of local materials deposited, in the Chelt Valley, about 40 feet above the present level of the stream. Thence they proceeded to a brickyard at Ham, where beds similar to those at Pilley (Leckhampton) were on view. Next the Glenfall was visited, by kind permission of Captain Willis, who joined the party. This is a deep gorge cut through Middle Lias Clays, showing the phenomena of stream denudation, and the process of gravel formation. The influence of harder and softer rocks, and the action of streams in regard to features of landscape were subjects for investigation.

Leaving the Glenfall, the party walked by way of Hewletts Hill to Cleeve Hill. The beds examined were similar to those seen at Leckhampton Hill—there being an almost exact repetition until the top of the Upper Freestone. Then a deposit known as Harford Sands appears, and one of the Directors called attention to certain nodular-shaped masses of quartzite which it contained, because these sands had been mistaken for Glacial deposits. Overlying the Harford Sands was seen the Snowhill Clay. Only a very thin representative of this bed is found at Leckhampton Hill. At Cleeve Hill it is about two feet thick; and in some parts of the district it is of economic value as a water-retaining stratum. Above the Snowhill Clay was seen Lower *Trigonia*-grit, and a succession similar to that of Leckhampton, up to the Notgrove Freestone. Then the interesting points wherein Cleeve Hill differs from Leckhampton Hill were pointed out in the Rolling Bank Quarry. The strata of the hills may be diagrammatically compared thus:

* The Bajocian of the Mid Cotteswolds, *Quart. Geol. Journ. Soc.*, vol. li.

LECKHAMPTON HILL.
Upper Trigonía Grit

Notgrove Freestone, 4 feet

Gryphite Grit

CLEEVE HILL.

Upper Trigonía Grit
T. Phillipsiana Beds } 23 feet
Bourguetia Beds }

Witchellia Grit, 4 feet

Notgrove Freestone, about
20 feet

Gryphite Grit

Thus at Cleeve Hill the Upper *Trigonía* Grit is separated from the Gryphite Grit by about 43 feet more strata than at Leckhampton Hill, which is about $5\frac{1}{2}$ miles distant.

The beds which make this separation are interesting from a palæontological point of view. The *Witchellia* Grit yields Ammonites of the genus *Witchellia* (sub-family *Sonnininae*), and *Terebratula wrighti*. Specimens of both were found by the members. The *Bourguetia*-beds show a large Gasteropod, *Bourguetia striata*; and their remarkable fauna of large Lamelli-branches called for general notice. The *T. phillipsiana*-beds yielded several species of Brachiopods, *Terebratula phillipsiana*, *Tereb. buckmaniana*, *Waldheimia* (*Zeilleria*) allied to *leckenbyi*, and an *Acanthothyris*.

The *T. phillipsiana* and *Bourguetia* beds are not found outside the Cleeve Hill plateau. Mr. Buckman called attention to the different strata which underlie the Upper *Trigonía* Grit, and showed their relative geographical extension by means of a map. He gave details as to the Bajocian denudation,* which has removed these and other rocks before the deposition of the Upper *Trigonía* Grit.

The bored surface of the beds immediately underlying the Upper *Trigonía* Grit was also pointed out.

At the foot of the hill carriages were in waiting to convey the party back to Cheltenham, stoppages being made to enable the members to visit two brickyards in the Middle Lias at the foot of Battledown, which is an isolated knoll capped by the Middle Lias Marlstone. These brickyards showed the clays yielding Ammonites in two distinct horizons. Thus:

<i>Liparoceras striatum</i>	}	Upper portion.
Do. <i>latæcostatum</i>		
<i>Cycloceras</i> , sp. sparingly		
<i>Cycloceras</i> , various spp., numerous	}	Lower portion.
<i>Phylloceras ibex</i>		
Do. <i>loscombi</i>		

Cæloceras centaurum was found loose.

On Tuesday, June 8th, the 8.33 train was taken for Stroud. Mr. Wethered was unfortunately not able to be present, but his place as Director was ably filled by Mr. C. Upton, of Stroud, who, with Mr. Buckman, met the party at the station on their arrival.

* See Bajocian of the Mid-Cotteswolds, *Quart. Journ. Geol. Soc.* vol. li.

Stroud is situated on the Middle Lias, and stands in the valley of the Frome, overhung on each side by Inferior and Great Oolite strata. Of the Middle Lias only a small exposure in the stream was pointed out, and no other sections were visible until the members reached the Pound at Rodborough Hill (Fig. 4) where they commenced the examination of the strata overhanging the valley. The Pea Grit formed the first hunting-ground, and yielded some fossils—*Terebratulina pisolitica*, *Rhynch. subangulata*. Then the Oolite Marl was attacked, whence the Nerineæ were obtained. It was pointed out that these beds are not necessarily exactly contemporaneous with beds bearing the same name which the party had seen at Cheltenham, and that, in fact, the fossil contents indicated that they were really later in date.

Passing to the Ragstone beds, the members were shown that at the quarry by Rodborough Fort the Upper *Trigonia*-grit rests directly upon Lower *Trigonia*-grit, all the other beds seen at Cleeve Hill the day before not being represented here.

At another quarry, showing a good section of *Clypeus* and an Upper *Trigonia*-grit, a most successful collection of characteristic fossils was made by the party.

Farther on, at Mount Surat, another quarry was visited, and attention called again to the bed upon which the Upper *Trigonia*-grit rested. This time it was the Upper Freestone.

The party then proceeded across Rodborough Common, noticing the "pit dwellings," and after lunch at the "Bear Inn" ascended the rise made by the presence of Fuller's Earth capped by Great Oolite. The famous Great Oolite Quarries of Minchinghampton were visited, with successful results. The Inferior Oolite was again seen at Walls Quarry, but as this is now disused it was not in a good condition for collecting. The party then returned to Stroud by the canal, and after tea at the "Imperial Hotel," took the 6.7 train to London.

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EXCURSION TO LEIGHTON BUZZARD.

SATURDAY, JUNE 19TH, 1897.

Director : A. C. G. CAMERON.*Excursion Secretary* : W. P. D. STEBBING, F.G.S.*(Report by THE DIRECTOR.)*

THE members assembled at Euston Station, and travelled by the 9.10 a.m. train to Leighton, where they were met by Mr. Cameron and a few friends from Leighton and Bedford. Carriages had been provided, and the drive was made by way of Rushmere and Heath to the Sand-pits at Stone Lane Hill. Dismissing the carriages there, the remainder of the excursion was carried out on foot.

Rushmere is a picturesque spot, in a side valley, cut through the Woburn Sands to the Oxford Clay. Formerly there was a chain of meres there, most of which are, however, now either silted up, or drained. Hard by, at the disused Nares Gladley brickyard, Oxford Clay was formerly worked, when the large *Gryphæas* (*G. dilatata*) which characterise the upper part of the Oxford Clay were found.*

Leighton Buzzard, is a region where Cretaceous rocks rest on a denuded surface of Jurassic Clays—the great plain which extends from Bedford by Fenny Stratford and Bletchley towards Aylesbury, being composed of Oxford Clay, Ampthill (Corallian) Clay, and Kimeridge Clay—the general dip being to the south-east. To the west of Leighton there is evidence of Kimeridge Clay; and the Lower Greensand rests indifferently on these great clay formations; it is composed mainly of arenaceous strata, hence the name, the Woburn Sands.

In the Stone Lane Hill pit the following section was seen :

	ft.
Laminated, clayey sand varying in colour, with a few pebbles at top	8-10
White sand	15-20

Those members who visited the white sand at Stone, near Aylesbury, on June 10th last, recognised here the similarity of the strata. It was suggested that colouration of the Lower Greensand might be caused by percolation through the mass, of water holding salts of iron in solution, the sand remaining white where such water had not penetrated. This view gave rise to some discussion at Shenley Hill, where the white sand showed colouration along the planes of bedding.

* See Teall, *The Potton and Wicken Phosphatic Deposits*, 1875, p. 27.
DECEMBER, 1897.]

Mainly composed of quartz (see analyses below *), the white (silver) sand of Heath and Stone is extensively dug for horticultural and for other minor purposes. At one time it was largely sent to Birmingham for glass-making, now very little of it is used for that purpose. Other sands are used for mortar-making, brick-making, and for filtering. Perhaps the most important of the sands to Londoners are those employed in the filter-beds of the great Water companies. The Lower Greensand is locally noted, also, for its fullers' earth near Woburn,† and for its phosphate bed at Potton and near Brickhill.

A large excavation, now disused, in the field adjoining the Stone Lane Hill Pits, exposed a thick deposit of Boulder Clay, with a miscellaneous assortment of stones, beneath which, there was a mass of cemented sand and gravel, part of the Glacial Drift. There is, however, no evidence anywhere near to show that the Glacial Sands extend over any considerable tract beneath the Boulder Clay.

On the way to Shenley Hill, Mr. Bushell, of Heath House, kindly invited the party in to see the fine old staircase (considered to be of Jacobean age) and the massive door that guards one entrance. Accompanied by the proprietor, the party then moved on to the disused pit in the field adjoining Heath House. Here, the Gault overlies the Lower Greensand and overlaps its margin, as it does in the south-west of England. Entering the pit, the members were confronted with a massive ledge of sand-rock, deeply-stained and cemented into carstone by the peroxide of iron, the tone being a rich red or reddish-brown. In parts this staining is bronze-like, and beautifully iridescent in places. Fortunately Mr. H. C. McNeill, A.R.S.M., obtained a photograph‡ of the pit, as the rock will soon be broken up and removed.

Passing over the Boulder Clay on the top of Shenley Hill, the party next came to the recently-opened pits (Garsides), where the white sand is extensively dug from beneath the Gault. Here, the junction is marked by a nodular bed of ochreous clay, and iron-stone. Layers of fine shingle occur in the sand, and where they are met with the sand is screened—the coarser pebbles forming a very useful gravel. Of a handful of pebbles taken at random, the majority were lydite, but flint and quartz occurred. Drift wood § was found, but no other fossils were seen.

* ANALYSES OF THREE SAMPLES OF WHITE SAND AT HEATH.
(From Mr. E. W. Lewis' *Lectures on Geology of Leighton Buzzard*, 1872, p. 61.)

	I.	II.	III.
Silica	98.50	99.00	98.88
Alumina ... ..	.78	.32	.33
Carbonate of Lime ... ..	.30	.20	.15
Oxide of Iron... ..	.42	.50	.56

Contributed by Merson Chance, of Birmingham.

† Beneath the fullers' earth the sands are white and cemented into stone.

‡ Now in the Collection of the British Association.

§ Mr Lewis, a former schoolmaster of Leighton, in his *Lectures on the "Geology of Leighton Buzzard,"* published in 1872, records the finding of a "tree trunk, eight to nine feet long and one foot in diameter in a sand-pit near St. Andrew's Church."

Grovebury Siding Pits, adjoining the L.N.W. Railway (Dunstable branch), were next visited. Here, a low hill in the Lower Greensand, margined by Alluvium and Valley Gravel, is capped with an isolated patch of Chalky Boulder Clay. The Boulder Clay is stiff and stony, with many scratched rock-fragments. It rests here and there on sharply false-bedded Lower Greensand, without any signs of disturbance in the underlying beds. Elsewhere the ice has stripped off masses of the sand, and incorporated them with the Boulder Clay.*

The Lower Greensand was again seen in the pit adjoining the Gas House, and the remarkable diagonal or cross bedding was there also well displayed. Mr. H. C. McNeill succeeded in obtaining a photograph.†

Before the members returned to town, tea was partaken of at the Elephant and Castle. After the thanks of the Association had been heartily accorded to the Director, on the proposition of Mr. Geo. Potter, F.R.M.S., the party dispersed.

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EXCURSION TO REDHILL AND MERSTHAM.

SATURDAY, JUNE 26TH, 1897.

(See page 113.)

EXCURSION TO WOKING.

SATURDAY, JULY 3RD, 1897.

Director: F. MEESON.

Excursion Secretary: MISS M. C. FOLEY, B.Sc.

(Report by THE DIRECTOR.)

THE members left Waterloo Station by the 1.50 p.m. train for Woking, where they were met by the Director, who led the way to the residence of Mr. Britton, of Caer Brito, who had kindly given permission for the party to visit his grounds.

Attention was first drawn to a section showing the junction of the Middle and Lower Bagshot Beds, of which an account has been published by Messrs. Monckton and Herries.‡ It is called

* See Report of Director-General of the Geological Survey for 1896, p. 79.

† Now in the Collection of the British Association.

‡ *Quart. Journ. Geol. Soc.*, vol. xlii, p. 414.

a “road cutting,” but is really a large sand-pit by the roadside, now enclosed. This section is close to the east end of the Goldsworth or Goldsworthy railway cutting, described by Prestwich in 1847, and which is shown in his diagram-section Fig. 1.

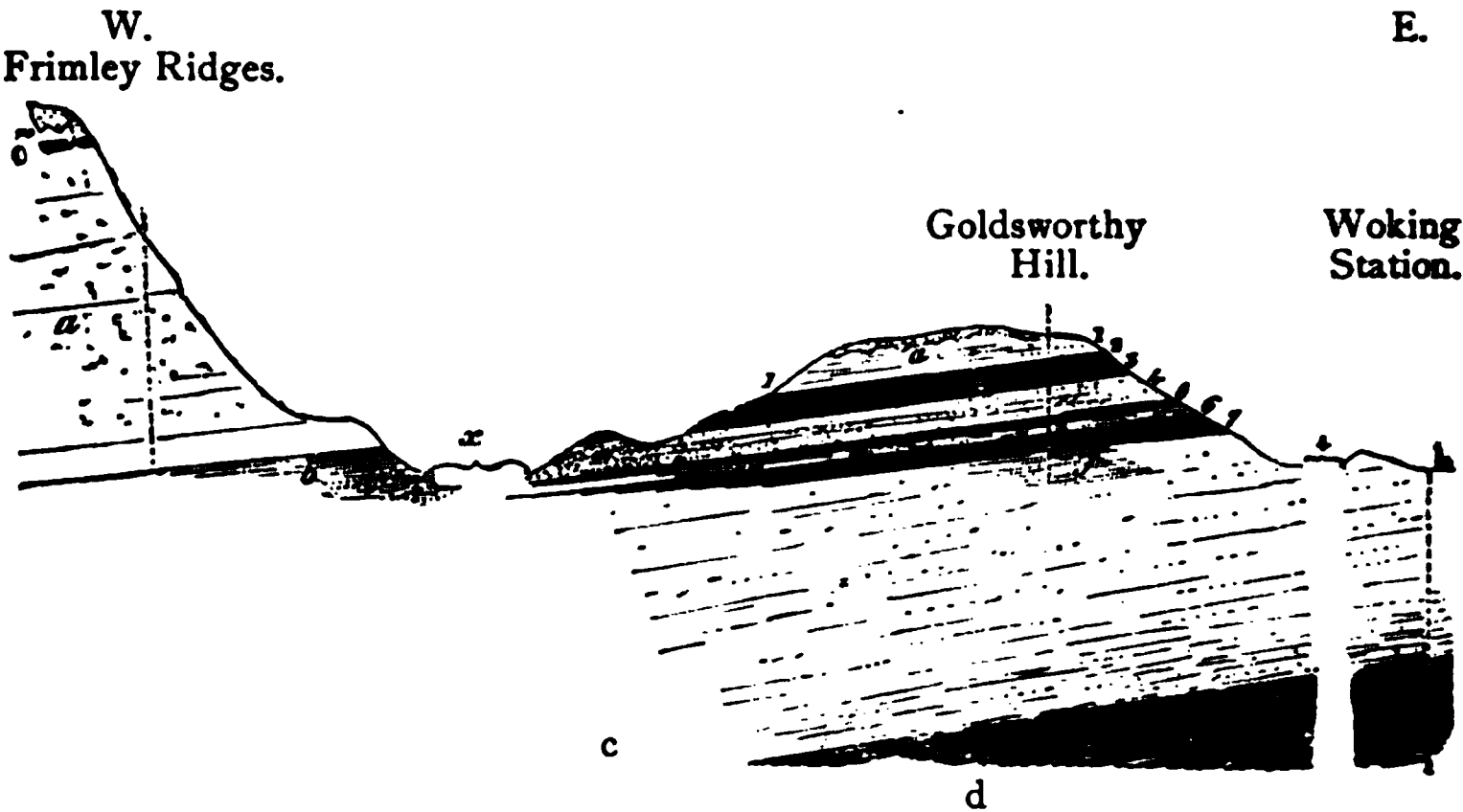


FIG. 1.—SECTION FROM FRIMLEY RIDGES TO WOKING STATION.—
Prestwich.

	Feet.
a. Upper Bagshot Beds, yellow sands (casts of shells).	
Maximum thickness, over ...	200
b. Middle Bagshot Beds	—
1. Greenish Sand, with a few Pebbles	2
2. Foliated Sandy Clays (brown)... ..	11
3. Grey Clay, with traces of lignite	1
4. Green Sand (teeth, bones, and casts of shells)	16
5. Compact Lignite	1
6. Sandy Clay, the upper part with green sand-tubes	6
7. Brown compact Clay, with sand and traces of vegetable remains	8
c. Lower Bagshot Beds	130
d. London Clay	—
x. Interval of 3 miles. † Interval of ¼ mile. In both these spaces the strata are continuous. ....Strata proved.	

The Director expressed a doubt whether the diagram-section was correct in showing any Upper Bagshot Sand at Goldsworthy Hill. Mr. H. W. Monckton said he thought that none occurred there, and that the pebble-bed mentioned by Prestwich was not the basement pebble-bed of the Upper Bagshot, but more probably a Middle Bagshot pebble-bed at a slightly lower horizon ; and in support of this he drew attention to Hook Heath, which is covered by a pebbly deposit, probably derived from the Upper Bagshot basement bed. Judging by the contour of the ground, he thought that these pebbles must have come from a bed

geologically higher in the series than the strata of the railway cutting.

The section in Mr. Britton's garden shows the green-coloured sand (Bed 4 of Fig. 1), the clay irregularly "pierced with green sand-tubes" of Bed 6, the clay of Bed 7 and its junction with the Lower Bagshot Sand. In the garden, attention was drawn to blocks of iron-sandstone, some of which, on examination, proved to be full of external casts of *Cardita planicosta*. The blocks were said to have come from the top of the rising ground close to the site of Mr. Britton's house, but no such bed was seen *in situ*.

Leaving Caer Brito, attention was drawn to an exposure by the roadside of green-coloured sands of Middle Bagshot age, and it was suggested that the level of this exposure, taken together with the sections in the garden above described, showed that the sands of the pits by Jackman's Nursery were undoubtedly Lower Bagshot.

It was in one of these sand-pits that Mr. R. S. Herries obtained the fossils which he exhibited at the Geological Society on June 8th, 1892, and described as "Marine Fossils from the Lower Bagshot Sands, Goldsworthy, near Woking."* In the same year the following remark upon this exhibit was published: "As for the 'discovery' of shells at Goldsworthy, it will be time enough to consider the bearing of this upon the general question when it shall have been satisfactorily determined that they are 'casts of "marine shells,"' and that they occur in the 'Lower Bagshot.'"+

The bed with the shells in question was soon found. It is a drab-coloured sand some three feet or more in thickness, crowded with casts and impressions of shells. Unfortunately, it is not easy to obtain good specimens for removal, but attention was drawn to several specimens of a bivalve with radiating ribs, which was probably a *Cardita*, and could hardly be a land or freshwater species.

Mr. Monckton said he thought that the members, after seeing this evidence, would have little doubt that the bed was of Lower Bagshot age and that the shells were marine.

Attention was directed to some sarsens which had probably been derived from a higher horizon than the sands of the pit, since they appeared to be water-worn.

After thanking Mr. Gribble, the proprietor, for allowing the Association to visit the sand-pits, the Director led the way over the end of Hook Heath and across the railway and the Basingstoke Canal to the Knap Hill brickfields, where the clay of Beds 6 and 7 of Fig. 1 is worked. In one place a section in the green-coloured sand of Bed 4 was seen, and in it a few teeth of *Lamna* were found by the members of the party. This find was

* *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 487, and *Proc.*, p. 188.

† *The Bagshot Beds of Bagshot Heath* (a rejoinder), by A. Irving, D.Sc., F.G.S., 1892.

of considerable interest, as it was from Bed 4 at Goldsworthy cutting that Prestwich obtained most of the fish remains of which a list is given in his paper on the Bagshot Sand.*

From Knap Hill the party proceeded to the common at Horsell Birch, where there is a large deposit of pebbles worked for road metal. This deposit has already been described in the PROCEEDINGS.†

A road across the common was then followed, and a fine section in Lower Bagshot Beds on the common, northward of Potter's Corner, was examined.

This completed the programme of the excursion, and the members were invited to the Director's house, where some specimens, including a tooth of a shark, from the beds passed through in sinking a well at Brookwood Asylum were exhibited. An excellent repast was provided by Mrs. Meeson, to which full justice was done. Before leaving, Mr. Monckton, on behalf of the members present, thanked Mr. Meeson for the trouble he had taken in arranging the excursion, and for acting as Director, and Mrs. Meeson for her kind hospitality. The party then returned to town by the 7.36 p.m. train.

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See also "Record of Excursions," p. 286.

EXCURSION TO PETERBOROUGH.

SATURDAY, JULY 10TH, 1897.

Directors : A. N. LEEDS, F.G.S., AND A. S. WOODWARD, F.G.S.

Excursion Secretary : R. S. HERRIES, M.A., Sec. G.S.

(Report by THE DIRECTORS.)

THE object of this excursion was to examine the strata at the top of the Lower, and at the base of the Middle Oolites ; also to visit the private museum of Mr. Leeds, who has devoted many years to the collection and preservation of the fossil vertebrata of the

* *Quart. Journ. Geol. Soc.*, vol. iii, p. 390.

† *Proc. Geol. Assoc.*, vol. xi, p. 17.

Oxford Clay. The party left King's Cross at 10.15 a.m., arriving at noon at Peterborough, where carriages were in waiting.

By kind permission of the authorities of the Great Northern Railway, they proceeded, under the guidance of Mr. T. R. Johnson to a fossiliferous exposure of the Cornbrash in the Spital goods siding. While there, attention was directed to the remarkable persistence and uniform character of this thin marine stratum across England, as compared with the formations immediately above and below it. After a brief halt in the city, the party drove about two miles south to Fletton, where there are several large pits in the Oxford Clay worked for brick and tile manufacture. Considerable time was spent in one of the largest of these excavations, whence Mr. Leeds has obtained many fine specimens. The stratification of the clay by thin layers of more or less broken shells was noted, and many septaria were examined for better-preserved fossils. Mr. Leeds pointed out how the vertebrate skeletons occurred, spread over well-defined old floors in the clay, and could thus with care be recovered almost in their entirety. From Fletton the party drove two miles west to the classical section of Great Oolite in the railway cutting at St. Botolph's Bridge (Bottlebridge), where the intensely-hard, shelly limestone was found to be much obscured by vegetation. On the return to Peterborough some members visited the extensive pits in the Pleistocene gravels near the village of Woodstone, and late in the afternoon the whole party proceeded four miles eastwards to Eyebury, the residence of Mr. Leeds, where they were hospitably entertained by Mrs. Leeds.

Mr. Leeds' Museum now contains only his most recent discoveries, the greater part of the collection made by his brother (Mr. Charles E. Leeds) and himself during the past thirty years having been acquired by the British Museum (Natural History), where the principal specimens are exhibited. The members, however, had much to see, and were able to realise how prolific was the reptile and fish-life in the Oxfordian sea. Many of the species have not yet been fully studied, and it is thus not possible to compile a complete list of the forms represented; but the following table gives the information up to date:

LIST OF VERTEBRATA DISCOVERED BY MESSRS. LEEDS IN THE OXFORD CLAY OF THE NEIGHBOURHOOD OF PETERBOROUGH.

REPTILIA.

DINOSAURIA.

Omosaurus durobrivensis, Hulke.

Ornithopsis leedsi, Hulke.

Sarcolestes leedsi, Lydekker.

Camptosaurus leedsi, Lydekker.

CROCODILIA.

- Steneosaurus* (various undetermined species).
Metriorhynchus (various undetermined species).
Suchodus durobrivensis, Lydekker.

ORNITHOSAURIA.

The bones of one individual.

SAUROPTERYGIA.

- Murænosaurus plicatus* (Phillips).
Murænosaurus platyclis, Seeley.
Murænosaurus veloclis, Seeley.
Cryptoclidus oxoniensis (Phillips).
Peloneustes philarchus (Seeley).
Pliosaurus ferox (Sauvage).

ICHTHYOPTERYGIA.

- Ophthalmosaurus icenicus*, Seeley.

PISCES.

ELASMOBRANCHII.

- Hybodus obtusus*, Agassiz.
Asteracanthus ornatissimus, Agassiz.
Asteracanthus var. *flettonensis*, A. S. Woodward.

CHIMÆROIDEI.

- Ischyodus egertoni*, Buckland.
Ischyodus beaumonti, Egerton.
Pachymylus leedsi, A. S. Woodward.
Brachymylus altidens, A. S. Woodward.

TELEOSTOMI (ACTINOPTERYGII).

- Lepidotus macrocheirus*, Egerton.
Lepidotus latifrons, A. S. Woodward.
Lepidotus leedsi, A. S. Woodward.
Heterostrophus sp.
Mesturus leedsi, A. S. Woodward.
Caturus (various undetermined species).
Eurycormus egertoni (Egerton).
Osteorachis leedsi, A. S. Woodward.
Hypsocormus tenuirostris, A. S. Woodward.
Hypsocormus leedsi, A. S. Woodward.
Leedsia problematica, A. S. Woodward.

Many special memoirs have been published upon the Leeds Collection, and they are enumerated in the list appended to this report. They are too lengthy to be abstracted here, but brief references are made to them (by number) in the following summary of the principal features of the collection.

The land-reptiles (Dinosauria) are represented only by fragments, namely, some vertebræ, two pelves (3, 5), two femora (3, 4), one

piece of jaw (8), and some detached teeth. These are, however, of great interest, and the remains of *Ornithopsis* are of gigantic size. The Crocodiles *Steneosaurus* and *Metriorhynchus* (10) are represented by nearly complete skeletons of a truly marine type, with very large hind limbs, relatively small fore limbs; and *Metriorhynchus* is proved to have been destitute of dermal armour. *Suchodus*, with relatively large teeth, is known only by part of the head (6). The Pterodactyles, as might be expected from their mode of life, are scarcely known; but it is very curious that not a single fragment of a Chelonian has hitherto been discovered. The Sauropterygia, or allies of *Plesiosaurus*, predominate in the collection (1, 7, 9, 11-18), and there are skeletons of individuals of all ages, from the very young to the extremely old (14). The Ichthyopterygia are represented by an almost toothless ally of *Ichthyosaurus*, with comparatively broad and flexible paddles (*Ophthalmosaurus*, 2). Fish-remains are very abundant, and important as supplementing our knowledge of the Upper Jurassic fauna in the Lithographic Stone of Germany and France. Whereas the Continental fossils display the general contour of the various fishes embedded in very hard limestone, the specimens in the Leeds Collection were originally macerated and buried in soft clay, from which the different bones can be washed and examined separately. There are fine groups of teeth of *Hybodus* found in association with the jaws of this shark. There are also many still finer groups of the teeth named *Strophodus*, in undoubted association with the fin-spines named *Asteracanthus*, and the hooked head-spines named *Sphenonchus* (19). Chimæroids are known only by detached dental plates and fragments of spines (21). The ganoid fishes are most numerous and add much to our knowledge of the structure of the skull of these primitive types.

The specimens of *Lepidotus* (28), *Caturus* (24), and the Pycnodont *Mesturus* (23) are especially fine; and those of *Mesturus* have shed entirely new light on the interpretation of the Pycnodontidæ. There is only one form which cannot yet be approximately determined, namely, *Leedsia problematica* (25, 26), which is represented by gill-rakers, fin-rays sometimes five feet long, and other miscellaneous bones which have not been identified. Similar fossils occur in the Oxford Clay of N. France, and in the Kimeridge Clay of Dorsetshire, but there is no clue to their true nature.

The party drove back from Eyebury to Peterborough, returning to London by the 6.49 p.m. train, due at King's Cross at 8.30 p.m.

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EXCURSION TO BISHOP'S STORTFORD.

SATURDAY, JULY 17TH, 1897.

Director: A. IRVING, B.A., D.Sc. (LOND.), F.G.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

(Report by THE DIRECTOR.)

THE members left Liverpool Street at 2.30 for Bishop's Stortford, where they were joined by the Director.

The object of the excursion was to study the Stratigraphy of the Upper Valley of the Stort, which includes the Senonian (“Chalk with Flints”), the Woolwich and Reading Beds, the London Clay, the Stratified Gravels, and the “Boulder-Clay,” with its many variations.

I. *The Chalk*.—The pre-Tertiary plane of abrasion of this
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formation is shown by its outcrop on both sides of the Stort Valley, and also by measurements taken in well-sections to the east and west, to be now at about 190 feet O.D. The formation appears to have been planed down to the zone of *Micraster coranguinum* before the Reading Beds were deposited.

Well sections in the Valley of the Stort show that along that line of erosion the Chalk underwent such extensive sub-aërial waste in later Tertiary (and perhaps early Glacial) times as to be channelled to a depth of 190 feet vertical, 170 feet of which is now filled up with Glacial detritus. This valley therefore presents features similar to those of the Valley of the Cam, as described by Mr. W. Whitaker (*Quart. Journ. Geol. Soc.*, vol. xlv, pp. 333-340).

II. *Woolwich and Reading Beds.*—These are best seen in their exposures on either side of the Stort Valley, where there are extensive brickyards. They occur in positions precisely similar to those in which they are met with on either side of the river Kennet at Reading; but they are less argillaceous here than at Reading. Green-coated flints are common in their basement-bed. In the Rye Street Brickyards (west side of river) these beds show signs of extensive erosion, though the section has not yet been carried sufficiently far into the flank of the hill to show the age of the overlying deposits, and to decide the question whether the erosion referred to is “contemporaneous,” or a part of the later denudation of the country. One of these overlying deposits is (in one part of the section) a curious jumble of sand, flint-pebbles, and nodules of limonite.

III. *London Clay.*—On the slopes of the valley this formation is largely obscured by Quaternary Drift. A good section of it was seen at the top of the field adjoining the brick-yards belonging to Mr. J. L. Glasscock. The workmen assert that below the present bottom of the pit they come to a bed of flint pebbles. (This pebble-bed undoubtedly occurs in some clay-pits at Birchanger, about half a mile distant, and contains at that place many shells of oysters, some of which are much worn by sand and water.) Sharks’ teeth occur at both localities.

IV. *Stratified (Plateau) Gravels.*—These occur at about 220 ft. O.D., capping low hills on both sides of the Stort Valley. The best sections of them were seen in the Thorley Pits by the London Road, near Twyford House, the proprietor of which, Laurie Frere, Esq., had most kindly caused three clean vertical sections to be prepared for the members of the Association to examine. About 20 ft. of gravel is exposed to view. The gravel lies on an eroded surface of London Clay, and upon it there rests 4 to 6 ft. of undoubted Boulder Clay. The two deposits are quite distinct; there is no passage from the one into the other, the gravels as well stratified as such deposits can be; they have their interstratified beds of coarse sand, as the plateau-gravels of Berks

frequently have, and as regards structure and arrangement agree with them in all respects. Their materials show that they belong to the Northern and Mercian Drift. Few subangular and discoloured flints are found in them, as compared with the plateau-gravels of the south side of the Thames Valley, which belong to the Southern Drift; but flint pebbles are numerous (here as there), mingled *here* with numerous pebbles (large and small) of quartz and quartzite (white, pink, and liver-coloured). These are identical with the pebbles of the Bunter Sandstone of the Midlands. A few subangular blocks of Sarsen stone occur, generally (along with the larger pebbles) near the base of the gravel. Rolled masses of Millstone Grit and of Coal-measure Sandstone can be recognised. The materials of the gravel diminish in coarseness, with an increasing proportion of sand, as we work up the face of the pit.

In another gravel-pit, about half a mile off on the other side of the valley, at about the same altitude, this differentiation of materials is even more marked, about 10 ft. in the upper part consisting of what is really a *gravelly sand*, with pronounced false-bedding, and this is succeeded upwards by thick beds of simple sand, with much irony investment of the grains, the whole overlain by a glacial deposit of a more gravelly nature than in the Thorley Pit.

[At Stansted, some four miles to the north, similar gravels (with some differences of detail) occur, overlain by a glacial deposit of that extreme flinty character, which is so often substituted for the Boulder Clay proper in these parts.]

Everything observable in these gravels points to a riverine origin for them, and their materials point to the Triassic regions of the Midlands as (in part) their source. It is hardly possible to say whether the materials from the Carboniferous are mediately or immediately derived.

The Director suggested that the gravels belong to a series of deposits laid down along the lower courses of rivers, which drained the Mercian area at a higher relative level, during the great Miocene and Pliocene elevation of North-western Europe, at a time when the present Chalk Escarpment — and therefore the present Mercian river-system — had no existence. (The map contained in Prof. Zittel's work, *Aus der Urzeit*, was referred to in illustration of this.) The gap in the Chalk hills about Clavering and Newport (watershed of the Stort and the Cam) represents, probably, the old channel down which the Mercian waters flowed into the Tamisian area.

At Start Hill, nearly two miles to the east, the gravel (about 290 ft. O.D.) is of a different type. It is probably a reconstructed Bagshot pebble-bed, with some admixture of foreign materials, and may without much difficulty be referred to Prestwich's "Brentwood Series" (see *Quart. Journ. Geol. Soc.*, vol. xlvii,

p. 181). Members of the Association examined the nature of its materials in the gravel on the drive of Hockerill Vicarage, and were hospitably entertained by the Director after the afternoon's walk was over.

V. "*Boulder Clay*."—As a comprehensive term, this includes many varieties of deposits, if used as an equivalent of the term "Glacial Drift." They are all, however, local representatives of the "Chalky Boulder-Clay" of the East Anglian country, varying from a normal "Boulder-Clay"—such as that which lies upon the stratified gravel in the Thorley pit, described above—to a deposit made up almost entirely of angular weathered flints, with a few quartz—and quartzite—pebbles.

Even within such a small area as the churchyard of Hockerill Parish we find in the graves such varieties as an almost pure (reconstructed) chalk with angular black flints, a stiff tenacious clay, a fine and sandy gravel with small pebbles and chalk detritus, and an irony, sandy gravel with no chalk at all. Jurassic fossils (Belemmites, Gryphææ, Oysters) from the Mercian Jurassic rocks are of quite common occurrence in the typical "Boulder Clay," wherever it is met with.

The only hypothesis with which such facts seem to harmonise is that of transport of materials from the Mercian uplands by "ice-rafts" floating and melting away in a great extra-morainic lake, the idea of which was so well worked out by the late Prof. Carvill Lewis. (See his communication to the British Association, Manchester meeting, 1887, and the *Glacial Geology of Great Britain and Ireland*, Longmans & Co., 1894.)

VI. The "*Herts Puddingstone*."—Very fine examples were seen and examined in the grounds of Oak Hall, by the kind permission of Mr. G. E. Pritchett, F.S.A. Since the Director came into this part of the country to reside he has recognised in these, mere pebbly varieties of Sarsen Stones, and has been happy to find that Mr. W. Whitaker, of the Geological Survey, has thought the same "for thirty years and more." The matrix is identical with the ordinary Sarsen, with its siliceous cementation of the sand-grains; and the included pebbles (all of flint) tell the tale of exposure to the same conditions and agencies as those by which the silica was set free from silicates to cement the whole into solid masses, as we find them. In Berks and Surrey we meet with such masses, as agglutinated portions of the Bagshot Pebble-bed, at St. Anne's Hill, Surrey,* the largest such block being seen on the hill-slope, and known in folk-lore as the "Monk's Grave." The Director considered the pebbly Sarsens of Herts to have had a similar origin, and, with the ordinary Sarsens (also common hereabouts), to form monumental evidence of the *quondam* extension over this (as over other parts) of the Tamisian area of the latest Eocene strata of the region.

* A. Irving, *Quart. Journ. Geol. Soc.*, vol. xliii, pp. 376, 377.

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LONG EXCURSION TO EDINBURGH AND DISTRICT.

JULY 26TH TO 31ST, 1897.

Directors : PROF. JAMES GEIKIE, LL.D., F.R.S., F.G.S. ; J. G. GOODCHILD, F.G.S., F.Z.S. ; and H. W. MONCKTON, F.L.S., F.G.S.

Excursion Secretaries : THOS. LEIGHTON, F.G.S., and E. P. RIDLEY, F.G.S.

(*Reports by* PROF. JAMES GEIKIE, H. W. MONCKTON, and R. S. HERRIES.)

THIS was the first visit of the Geologists' Association to Scotland, and the difficulty which had hitherto stood in the way, namely the obtaining of the necessary accommodation, was experienced at the outset. It was found impossible to house the party under one roof, as has hitherto generally been done, so it was decided to ask the members of the Association to find their own rooms as and where they liked. The Clarendon Hotel, if anything, formed the Headquarters, as here the Excursion Secretary and about a dozen others were to be found. This difficulty did not, however, prevent the excursion from being a very successful and well-attended one, and the unanimous verdict of those who took part in it was that it would not be long before the Association paid a second visit to Scotland. The bulk of the party arrived on Saturday night, and on Sunday, July 25th, Mr. Goodchild kindly met those who cared to accompany him at Holyrood, and conducted them over Arthur's Seat, The Lion's Haunch, Salisbury Crags and their surroundings, and later in the day after a heavy shower, almost the only rain experienced during the

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excursion, a party visited the Calton Hill under the same guidance. It is unnecessary to describe these excursions, as the locality has been so fully dealt with by Mr. Goodchild on p. 125 of this volume. The excursions proper are described below.

LONG EXCURSION.—BATHGATE HILLS.

MONDAY, JULY 26TH, 1897.

Director: PROF. JAMES GEIKIE, LL.D., F.R.S. L. AND E., F.G.S.

(*Report by* THE DIRECTOR.)

THE party reached Bathgate at 10 o'clock, and made at once for the hills. Near Kirkton the Director gave a short outline sketch of the geological structure of the district. The ground to be traversed showed a great succession of basalt-rocks with occasional tuffs, interstratified with which were limestones, sandstones, and shales. The strata ranged from the Calciferous Sandstone series up to the top of the Carboniferous Limestone. The lowest bed visited was a fissile cherty limestone, seen in the old quarry at Kirkton. The limestone itself was fairly well exposed, but the overlying sedimentary beds were somewhat obscured. Much tuffaceous matter is distributed through the limestone, the rock itself being abundantly interlaminated with chert, showing in places much puckering, and very frequently a kind of brecciiiform character. Obscure plant remains were seen in the limestone, which is believed to be of freshwater origin. It is underlaid by tuff and basalt, and the overlying shaly beds are also very tuffaceous in places. These last were directly covered by a somewhat vesicular basalt-rock much decomposed. From the upper part of the shaly beds, just below the basalt, a number of Carboniferous plants were obtained, referable chiefly to *Lepidodendron*, *Calamites*, and *Sigillaria*. The party next struck west in the direction of dip, passing over basalts with an intercalated bed of marine limestone. Unfortunately the old quarries in which this limestone was formerly worked are now completely overgrown, and the rock could not be examined. Traversing the outcrop of this limestone and the overlying basalts, the outcrop of the main limestone (Hurlet seam) was reached, and a halt was made in order to hunt for fossils. These, although abundant, are not readily broken out of the rock, and the calcareous shales which accompany the limestone are not now exposed. Amongst the fossils obtained were various corals (*Aulophyllum*, *Zaphrentis*, *Lithostrotion*), a number of brachiopods (*Productus giganteus*,

P. semireticulatus, *Spirifera*, *Terebratula*, etc.), some molluscs (*Bellerophon*, *Pinna*, *Orthoceras*), and a polyzoon (*Fenestella*). Grains, patches, and seams of bitumen were observed in cracks and joints in the limestone. At the Gala Braes specimens of a fine-grained basalt were obtained. This rock is intrusive—apparently a sheet or sill. The old limestone quarry near the Knock was next visited. The rock here is another outcrop of the “Hurlet,” showing the same characters as in the quarries already inspected. It is underlaid by bedded tuff, and capped by lava-form basalt. The party, however, was interested in the section which exhibited one of the well-known east-and-west basalt dykes which here cuts across the limestone strata. The dyke was well exposed, the strata having been removed on one side, so that the butt-ends of the irregular columns could be studied in detail. This vertical rock-face was glacially smoothed, and showed parallel striæ pointing from west to east. The party having rested here for luncheon, passed on to the South Mines quarry, where a considerable series of strata was seen in section. The limestone (Hurlet seam) is here overlaid by 50 feet or thereabout of sandstones and shales. Plant remains were seen both in shales and sandstones, but none in a good state of preservation. Ripple marks, worm tracks, and worm borings were common in the sandy shales. A thin dyke of basalt was inspected. The rock was fine-grained, and in contact with the black shales had been converted into “white trap.” At Silvermines the site of certain old mines from which galena and other ores were formerly obtained was pointed out. The veins, however, could not be inspected, a few fragments of galena in some of the old rubbish heaps being all that can now be seen.

The party then left the outcrop of the Hurlet, and walked eastward to Tartraven, where a thin marine limestone, interstratified with basalt, crops out at a lower horizon than the Hurlet. This thin limestone is believed to be the same seam as that which occurs at some little distance above the freshwater limestone at Kirkton, and which, as already mentioned, is now entirely obscured. Unfortunately the old quarry at Tartraven proved to be similarly obscured—the section being quite covered up and overgrown. Leaving Tartraven, the party struck northwards, skirting the Riccarton Hills, which consist of a succession of bedded basalts; and again at Bee Craigs one of the great east-and-west dykes was encountered. This dyke attains a thickness of 200 feet. Continuing northwards, the Hurlet limestone was again met with at Hillhouse. Here it is overlaid by bedded basalt, showing beautiful columnar structure, which was much admired.

The afternoon being now well advanced, Linlithgow was made for. The road thither offered no particular object for study. It traverses the basalts which overlie the Hurlet. Near Preston

House, however, it crosses yet another of the east-and-west basalt dykes. Linlithgow was reached in time to allow of a brief inspection of its famous palace—the former residence of Scottish royalty.

LONG EXCURSION.—THE PENTLAND HILLS.

TUESDAY, JULY 27TH, 1897.

Director: J. G. GOODCHILD, F.G.S., F.Z.S.

(*Report by* R. S. HERRIES, M.A., SEC. G.S.)

LEAVING the Caledonian Station by the 9.50 train, the party arrived at Balerno at 10.21. They then walked southwards across Lower Carboniferous Beds to Bavelaw Castle, near which they visited a small quarry in highly inclined Silurian Rocks (Ludlow). The Director explained that these Silurian Rocks form the core of the Pentlands, and that on their upturned edges rest unconformably the great Old Red Series (Caledonian Old Red) of the Pentlands, as well as the Upper Old Red and the Carboniferous Beds (see plate VI.). At this quarry a few fossils were obtained, and some basalt dykes were pointed out. The party then proceeded into the heart of the Pentlands amid the most lovely scenery, the path taking them between Hare Hill, where the nearly horizontal beds of the Upper Old Red were well seen, and Black Hill, which is a microgranite intrusion of Old Red age. At Loganlee the Conglomerates at the base of the great Old Red Volcanic series, called by the Director the Caledonian Old Red, were well seen by the side of the burn, and yielded many beautiful pieces of jasper and other rocks. This conglomerate rests on Silurian rocks, similar to those seen at Bavelaw Castle, and some time was allowed the members to search for fossils. Before leaving this spot the Director made some remarks on the glaciation of the district, and he pointed out the well-known boulder of mica schist from the Highlands, mentioned on page 121. Scald Law was then climbed, and in descending the eastern slopes the great volcanic series, consisting of andesites and trachytes with occasional beds of tuff, was traversed. In an exposure of one of the latter attention was drawn to a globular structure, which has been recognised as caused by raindrops falling through an atmosphere charged with fine volcanic dust. At the foot of the hills the "porphyrite" of Carnethy was seen, and some beautiful specimens of the included agates obtained (page 121). A fault there brings down the Carboniferous again, and the way lay across these beds to Penicuik, whence the return to Edinburgh was made by the 6.30 train.

LONG EXCURSION.—STIRLING.

WEDNESDAY, JULY 28TH, 1897.

Director : H. W. MONCKTON, F.L.S., F.G.S.*(Report by THE DIRECTOR.)*

It had been hoped that Sir James Maitland,* a member of the Association, would have directed the party on this occasion, but unfortunately he was detained in Edinburgh by business, and Mr. Monckton acted as Director. Mr. Goodchild also was present, and gave much assistance.

The members, some fifty in number, travelled from Edinburgh to Stirling by the Forth Bridge route, and on arrival carriages were found ready, and a start was soon made for Sauchie Muir.

After leaving the town the broad flat plain through which the River Forth flows was seen stretching away to the north and east. It is formed of marine alluvium, and has been classed with the 50 feet Raised Beach. The 100 feet Raised Beach was passed at the village of St. Ninians, where the road runs along it for a short distance, but no sections were seen.

At about two miles from Stirling the road passes close to the battle-field of Bannockburn, and the Bannockburn itself was crossed near the village Whins of Milton.

Reaching Sauchie the road runs in a westerly direction along the north side of the ravine, which follows the line of a long east-and-west fault. In this ravine the burn flowing out of Loch Coulter passes the great mass of intrusive dolerite which forms such a conspicuous feature in the scenery near Stirling. The "Jew's Quarry" in the dolerite was passed, but there was not time to examine it. The quarry has been already mentioned in our PROCEEDINGS.†

The party left the carriages close to a ford on the Bannockburn near Todholes, and assembled on an esker, where the Director gave an account of the geology of the district.‡ A small section in the esker was then noticed, and the esker seen to be composed of stratified sand and gravel.

The party then walked some distance up the Bannockburn, and collected fossils from the Hurlet Limestone, and from some dark calcareous shales associated with it.

Returning to the ford, the members walked across some fields and along the foot of Sauchie Craig, which is capped by the

* As these pages go to press, we regret to hear of the death of our kind host, Sir Jas. R. G. Maitland, Bart., F.L.S., F.G.S.—ED.

† Vol. xii, p. 249.

‡ See vol. xii, p. 242, and *ante* p. 152.

intrusive dolerite already mentioned, and in the face of which are disused workings in the Hurlet Limestone. At the foot of the crag are mounds and humps of interbedded igneous rock—the Porphyrite of the Geological Map.

The party then turned east down a ravine towards the house at Sauchieburn. The top of this ravine is at the small patch of bedded rock marked about half-way down the left side of the Sketch Map, Fig. 3, ante p. 154. In this patch are excellent springs, which give rise to the small burn running past the house. On the north of this ravine the dolerite gradually slopes down to the east (as shown in Fig. 2, p. 153), so that at a small quarry, marked 4 on the Sketch Map, the members were able to see the junction of the igneous rock with overlying shales.* On the south side of the ravine the dolerite descends much more gradually, and at Sauchieburn forms the capping of a high cliff which faces north-east, the bottom of the dolerite almost coinciding with the 400 feet contour line (see Sketch Map).

In the lower part of this cliff, then, are the small tongues and patches of igneous rock, marked 6, 8, 9, 10, 11 in the Sketch Map. The Director said he thought these patches were undoubtedly connected with the great mass of dolerite at the top of the cliff, and that they were of considerable interest. Unfortunately, there was not time to examine them. He mentioned that Sir James Maitland had found a patch of dolerite at the top of the cliff (locality 5 on Sketch Map), where the rock is strongly magnetic; and a specimen lying by the side of the path was tested with a compass by some of the members.

On arrival at the house at Sauchieburn, the members were received by Miss Maitland and entertained at luncheon, at the conclusion of which the President proposed a vote of thanks to Sir James and Miss Maitland for their kind hospitality, and Miss Maitland replied, saying that her father greatly regretted his inability to be present.

Leaving Sauchieburn, the members drove to the Howietown Fishery, where they were received by Mr. Thompson, the manager, who led the way to the various ponds and explained the system of working at a trout farm.

Some of the members were led by Mr. Goodchild to a large quarry in the intrusive dolerite at Millholm, and the party then started on the return drive to Stirling, and left by the 5.55 p.m. train for Edinburgh.

* At the *Conversazione* on November 3rd, Mr. W. J. Atkinson exhibited a specimen from this quarry showing the junction of the dolerite and the shale with fossils. On one side was a fragment of a *Productus*, and on the other, igneous rock

LONG EXCURSION.—BURNTISLAND AND KINGHORN.

THURSDAY, JULY 29TH, 1897.

Director: J. G. GOODCHILD, F.G.S., F.Z.S.*(Report by R. S. HERRIES.)*

THE party left the Waverley Station at 9.50 for Burntisland, on the coast of Fife, *via* the Forth Bridge. The first section inspected was a cutting on the railway, which had been passed through in the train shortly before reaching the station. The rock here had only recently been recognised as a picrite, and the Director drew attention to the formation of "white trap" at the junction between the intrusive and sedimentary rocks (p. 138). The party then climbed the hill to the Grange Quarry, noticing some fragments of Granton Shales on the way, from which coprolites and other fish remains were obtained. In the quarry the Burdiehouse Limestone, a thin but persistent bed, is exposed. The ascent was continued till the summit of the Binn of Burntisland was reached, where a halt was made for luncheon and for the examination of the very fine sections of volcanic agglomerate (see p. 137). The Director explained that this mass of agglomerate was an old neck, and that from this point in all probability a large proportion of the great mass of lavas and tuffs to the immediate north and east had been emitted. The agglomerate is traversed by several basaltic dykes. While on this elevated spot, from which a very fine view of the Firth of Forth was obtained, the Director took occasion to make some remarks about the depression and elevation of the land since the Tertiary period. The many islands which were seen dotted about, were, he said, the tops of old hills; after partial or complete submergence these had been brought again to light by the elevation of the land, evidence of which was to be seen in the raised beaches, four of which at different levels were to be seen from that spot. Coming down, there was no time to visit the Oil Shale Works, though the Director pointed out the character of the shale, as some heaps of tipped material were passed. The shales were seen to contain abundant fish scales, and a few teeth were obtained. The Dodhead Quarry was next visited, and the classic example of a "White Trap" intrusion was observed with much interest (see p. 139). The trap has forced its way up through the strata to a certain level, and then spreads horizontally between the layers of stratified rock. On one side it dies out quickly, but on the other it continues throughout the exposure, some 200 feet. A photograph of this intrusion, by Mr. H. C. McNeill, is reproduced on Plate VIII A. The figure in the centre is pointing out the root of the intrusion, while that on the right marks the point

at which the sheet thins out in that direction. The figure on the left has his hand on the bottom of the sheet of trap on that side. Time did not allow of an examination of the lavas at Pettycur Point, but they were well seen in the fine cliff overhanging the road, known as King Alexander's Crag. Passing through Kinghorn, the shore at Abden was visited, and the higher limestone bands of Yoredale age interstratified with lavas and tuffs were seen. Here a search was made for the Bone Bed (see p. 143), but, unfortunately, none of the party was successful in hitting upon it. The return to Edinburgh was made from Kinghorn at 5.51. Later on, the members dined together at the Clarendon Hotel, the Directors being the guests of the evening.

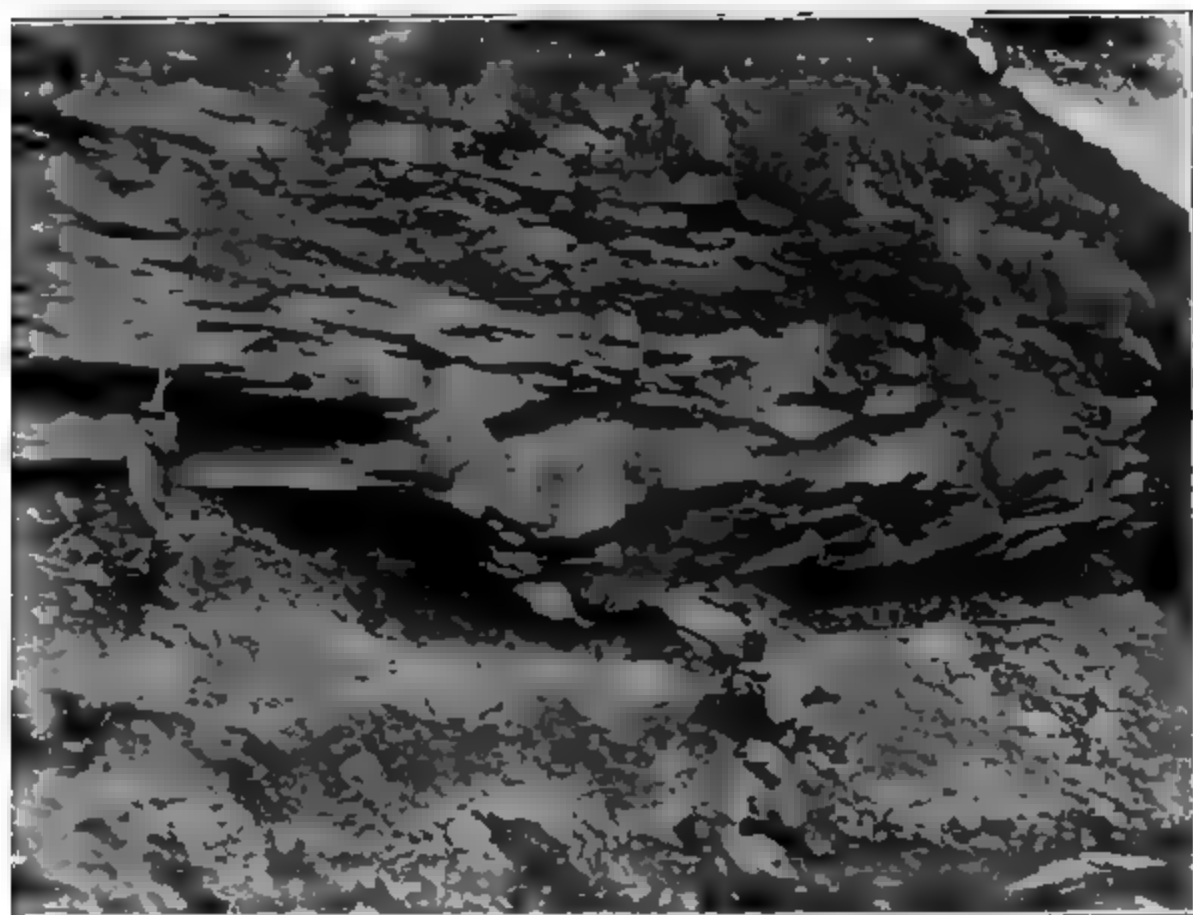
LONG EXCURSION.—COCKBURNSPATH.

FRIDAY, JULY 30TH, 1897.

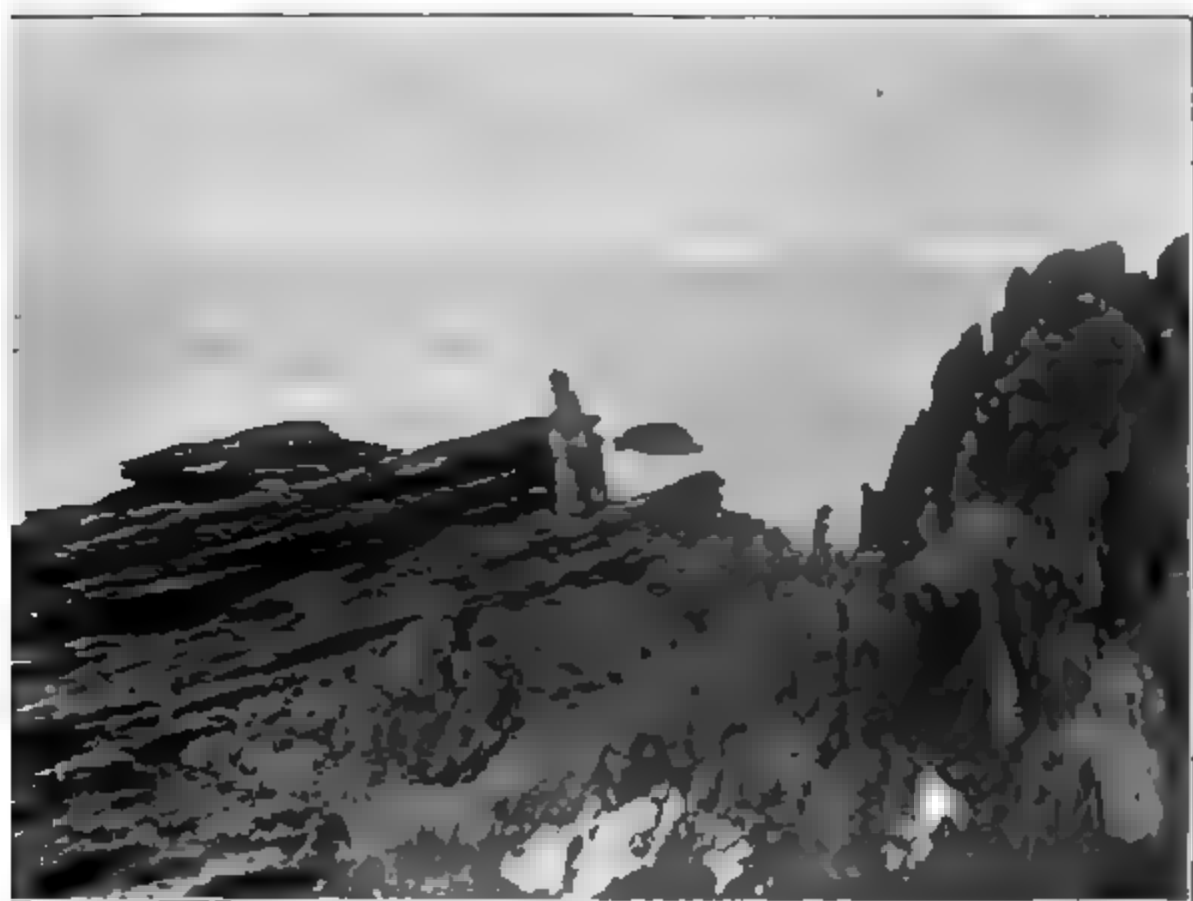
Director: J. G. GOODCHILD, F.G.S., F.Z.S.

(*Report by* R. S. HERRIES.)

A START was made nominally at 10.20 from the Waverley Station, the express being specially stopped at Cockburnspath, but owing to the trains from the north being very late, considerably more than an hour was lost, which necessitated some curtailment of the programme. Cockburnspath, or Copeth, which is in Berwickshire, is situated at the junction of the Lower Carboniferous with the Upper Old Red Sandstone. The party proceeded along the cliff about three miles to Siccar Point, where on the shore a magnificent unconformable junction is seen. Here the gently dipping beds of the Upper Old Red rest like tables on the edges of the almost vertical Silurian beds, striking at right angles to the coast. These beds belong to the Gala series, and are the equivalent in age of the Tarannon Shales of Wales. This fine junction is represented on Plate VIII B., reproduced from a photograph by Mr. H. C. McNeill. A halt was made here for luncheon, and an excellent group of the party was taken by Mr. James Pringle, of Copeth, who had accompanied the excursion. Proceeding along the coast southwards, the beds of the Upper Old Red were examined, and at least one specimen of a *Holoptychius* scale was picked up. The party then went inland to the Old Cambus Quarry, where the highly inclined and folded beds of the Gala group of the Silurian were again seen. Some time was spent here in searching for graptolites, and most of the



A.—WHITE TRAP INTRUSIVE INTO LOWER CARBONIFEROUS STRATA,
DODHEAD QUARRY, BURNTISLAND.



B.—UNCONFORMABLE JUNCTION OF UPPER OLD RED SANDSTONE AND
SILURIAN (GALA BEDS), SICCAR POINT, BERWICKSHIRE.

(From photographs by H. C. McNeill, A.R.S.M.)

members were well rewarded. On the return to Cockburnspath the Peaseburn was crossed, a very picturesque example of a dene, about the formation of which the Director made some remarks (see page 122). The return to Edinburgh was made by the 2.3 train.

LONG EXCURSION.—ELIE AND ST. MONANS.

SATURDAY, JULY 31ST, 1897.

Director: PROF. JAMES GEIKIE, LL.D., F.R.S. L. AND E., F.G.S.

(*Report by THE DIRECTOR.*)

It was at first intended that the party should proceed to St. Monans, and work back along the coast to Elie; but as the most interesting and important sections occur nearest to the last-named place, and the tide was flowing, it was considered advisable to visit the best sections first. The party assembled at Elie Harbour, in the centre of one of the remarkable volcanic necks for which this part of Fife is so noted. Here the Director gave a short outline of the various geological features to be studied. The region to be traversed lay wholly within the Carboniferous area, the strata representing the base of the Limestone series and the upper portion of the Calciferous Sandstone series. At Elie the prevalent dip is towards the west, while at St. Monans the inclination of the strata is easterly. At these two places the basement beds of the Limestone series are exposed, the stretch of coast-line between them showing the upper members of the underlying Calciferous Sandstones disposed in a series of more or less gentle, but sometimes sharp, anticlines and synclines. Between Elie and St. Monans no fewer than nine volcanic necks are exposed, and the main object of the Excursion was the examination of these and their relation to the rocks they traverse.

At Elie Harbour many interesting features were observed. The strata at the line of junction with the neck were much jumbled and shattered, often dipping in towards the neck at a high angle, and even in places standing on end. Here and there, also, the sandstones were baked and hardened so as to resemble quartzite and porcellanite. The neck was filled with agglomerate and tuff—the rock fragments consisting of sandstone, shale, limestone, basalt, diabase, etc. These fragmental materials showed a kind of rude bedding, having a distinctly centroclinal dip. Thin dykes and veins of basalt cut across the neck, and the adjacent sandstones and shales. Similar features characterised most of the necks subsequently visited, but were nowhere better displayed

than at Elie Harbour. The next neck examined was that of Shepherd Law, which measured not far short of twenty chains in diameter, or about twice the width of the neck at Elie Harbour. The junction of the agglomerate of Shepherd Law with the Carboniferous strata was particularly well seen. Here the latter were, as usual, jumbled and smashed and much hardened and baked in places. Searching the tuff, the party obtained a number of large broken crystals of hornblende and sanidine, scales of biotite and small garnets (pyrope). Sanidine and hornblende were also met with in the necks seen between Shepherd Law and Ardross Castle. At the latter place a thin limestone crops out. It is overlaid by shales, and underlaid by a few inches of blue clay, underneath which occurs a thin layer of coal resting upon a sandy underclay full of *Stigmara*. The shale above the limestone yielded many joints of crinoids and a number of other fossils, including *Productus*, *Lingula*, *Schizodus*, *Aviculopecten*, *Bellerophon*, *Nautilus*, etc. The large neck of Coalyard Hill was next crossed. Here the agglomerate presented much the same features as had already been studied—the party being particularly interested in the appearance of several dykes and veins of white trap, which cut across the junction of the neck with the surrounding shales and sandstones. Near Newark Castle two small necks were encountered. Neither of these exceeds forty yards across, yet each shows all the characteristic features of such structures. The strata at this place are thrown into a series of sharp anticlines and synclines, are much jumbled in places, and traversed by irregular intrusions of white trap. Two thin limestones crop out here, and the shales associated with them yielded a few fossils—chiefly *Lithostrotion*, *Aulophyllum*, *Poteriocrinus*, *Fenestella*, *Productus* (several species), *Orthis*, *Rhynchonella*, *Spirifera*, etc. These limestones dip east at a high angle below sandstones and shales, which are immediately truncated by the large neck at St. Monans. Traversing this neck the party found themselves upon the outcrops of the bottom limestones of the Scottish Carboniferous Limestone Series. The tide, however, had now come in too far to permit of a hunt for fossils, and the examination of the volcanic phenomena had occupied so much time, that it was necessary to make for the railway station on the return journey. A pleasant saunter of two and half miles brought the party back to Elie in time for the 4.10 p.m. train to Edinburgh.

This ended the official excursion, but a considerable number of the members who remained in Edinburgh were able to have the further advantage of Mr. Goodchild's leadership in an interesting ramble over Blackford Hill (see page 139), and a visit to the collection of Scottish Geology and Mineralogy in the Edinburgh Museum of Science and Art.

EXCURSION TO WHITCHURCH, OIVING, AND QUAINTON.

SATURDAY, SEPTEMBER 4TH, 1897.

Director: A. M. DAVIES, B.Sc., F.G.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by THE DIRECTOR.*)

OWING to the uncertainty of the weather, only a small party assembled at Waddesdon Manor Station, shortly before half-past eleven. A sharp half-hour's walk brought them to Pitchcott Hill, where the Director pointed out the features of the surrounding country. In the distance, south-westwards, the Chalk escarpment of the Chilterns bounded the view. Between was the low-lying Vale of Aylesbury, with its floor of Gault and Kimeridge clay, dotted with small hills and patches of rising ground, every one of which was capped by Portland Beds, with "Purbeck" and "Lower Greensand" at the top in many cases. The most conspicuous of the Greensand outliers was that on which Waddesdon Manor stood—a landmark for miles around.

The walk was continued to Oving, and here in a pit dug in the market gardens east of the village the following section was seen:

	Ft.	In.
15. Soil [and Drift ?]	1	0
14. "LOWER GREENSAND"	2	0
UNCONFORMITY.		
13. Limestone	0	7½
12. Clay	0	2
11. Limestone	0	2½
10. Clay	0	2
9. Crumbly Limestone with Ostracods and Fish-scales.	1	2
8. Shaley Clay with Ostracods	0	8
7. Limestone	0	1½
6. Marl	0	5
5. Sand	2	3
4. Clay	0	3½
3. Sandy Limestone	0	5½
2. Clay	0	3
1. Massive Limestone with <i>Trigonia</i> , etc.	3	6
	13	3½

The line between Portland and "Purbeck" may, perhaps, be drawn below No. 8, though comparison with a section described by the late Prof. Green from near by* would suggest that it

* See H. B. Woodward, "Jurassic Rocks of Britain," vol. v, p. 228, *Mem. Geol. Survey*.
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should come at the bottom of No. 2. The Greensand dies out a few yards to the north of this pit.

In another exposure in the same fields massive Portlandian was seen overlying clayey beds, with limestone again below. At one point a large mass of the upper limestone seemed to have slipped down into the clays, squeezing them out to either side. Yet the top of the series was quite level, and on it rested a remarkable clay with rounded pieces of limestone. The Director was uncertain what age to give this clay.

The next pit examined was on the south side of the road, a little nearer to Whitchurch. Here the following section of "Lower Greensand" was exposed :

	Ft.	In.
Soil and Drift with Flints, etc., about	1	0
White Calcareous Clay	5	6
Ironstone	0	6
Sand (yellow, some bands clayey, ironstone at base)	2	6
Fine White Sand (yellow in parts)	6	0

The whole dipping to the east.

These beds have a general similarity to those at Stone ; but the sand, as far as exposed, is finer, and free from pebbles. A few pebbles, however, were found in the ironstone bands. As to age, it might be anything between Purbeck and Gault.

The party proceeded to Whitchurch village, where the outcrop of Portland Stone in the roadway was noted ; and after lunch a clay-pit was visited near the fork in the road at the south end of the village. This is stated to be Kimeridge rather than Hartwell Clay ; but the sections were obscure, and nothing but small oysters (*Exogyra nana*?) and fragments of *Ammonites biplex* were found on the spoil heaps. Following the North Marston road to the eastern crest of the hill, a small quarry showing Portland Stone overlying glauconitic sand was examined ; this was the first exposure seen of the "Portland Sands" of the Survey Map. These do not correspond to the similarly-named sands of Dorset, as they are Upper Portlandian. From the limestone above them numerous fossils (chiefly casts) were obtained : *Trigonia gibbosa*, *Cardium dissimile*, *Cerithium portlandicum*, *Natica*, *Ostrea*, etc.

The party next made their way to Quainton Road Station, and a short walk down the line brought them to the termination of the new line of the Great Central Railway (better known as the Manchester, Sheffield and Lincolnshire). In the cuttings there large specimens of *Gryphæa dilatata* were soon found in abundance, indicating that Oxford Clay had been reached without any sign of Corallian beds intervening between it and the Kimeridge Clay. The Corallian is, in fact, represented here by clay, so that both its upper and lower boundaries are difficult to determine. That at this point the lower boundary was close at hand was suggested by the finding of an *Ostrea discoidea*,

characteristic of the Ampthill Clay (Corallian) of Bedfordshire. In the brickfield adjoining the railway a few small oysters were picked up; the Director had found *Belemnites* and *Ammonites cordatus* here on a previous visit. A block of limestone (apparently from a stone-bed in the clay) was noticed, and specimens taken.

An excellent tea at the Five Arrows, Waddesdon, completed an excursion that was a decided success, the weather having cleared in the afternoon, and the whole programme of a rather long walk having been carried out over ground quite new to the Association.

REFERENCES.

Geological Survey Map, Quarter-sheets 46 S.W. [and 45 S.E.]. Price 3s. each.
Geological Index Map, Sheet 12. Price 2s. 6d. (colour printed.)
Ordnance Survey Map (New Series), Sheets 219 [and 237.] Price 1s. each.
[The maps within square brackets cover only a very small part of the district.]

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EXCURSION TO OTFORD AND THE HOLMESDALE VALLEY.

SATURDAY, SEPTEMBER 18TH, 1897.

Director : A. SANTER KENNARD.

Excursion Secretary : A. C. YOUNG, F.C.S.

(*Report by THE DIRECTOR.*)

ON arrival at Otford the party proceeded to the large disused chalk-pit adjoining the station. The President announced that through unforeseen circumstances Mr. W. J. Lewis Abbott, who had intended to act as Director of the excursion, was unable to be present, but that Mr. A. Santer Kennard had most kindly volunteered to take his place. Mr. Kennard then pointed out that the chief feature of interest in the section was a rainwash overlying the Chalk. This deposit varies from one to six feet in thickness, and contains, especially at the base, large quantities of land shells. All the species, with one exception, may be found now living in the district. The age of the deposit is, without doubt, post-Roman, as proved by a Roman bronze pin found by the Director at the base of the hillwash resting on the surface of the Chalk. Other Roman remains were collected by members
DECEMBER, 1897.]

ON ROMNEY MARSH.

By GEORGE DOWKER, F.G.S.

*(Plate IX.)**(Read April 2nd, 1897.)*

THE subject of this paper includes the area of the south of Kent and Sussex, known as Romney Marsh proper, with the districts of the Walland, Guildford, and Denge Marshes, which stretch west from Hythe to Rye, a distance of about seventeen miles, and north from Dengeness to Appledore about twelve miles. This low-lying tract of Alluvium and Beach is for the most part below the sea-level at high water, and is protected from inundation by natural barriers of shingle and sand hills, except near Dymchurch, where there are sea-walls.

I shall endeavour to trace the history of this interesting district from prehistoric times, and describe the natural and also the artificial causes that have led to the reclamation of the Marsh from the sea.

For convenience I shall take the Geological Survey *Memoir* of the district, by Mr. F. Drew, published in 1864, and endeavour to show that in the *Memoir* the physical and historical evidences have been mixed, and that the latter do not support the conclusions arrived at. It would be impossible to do justice in this paper to the vast amount of historical facts relating to the district, which has been accumulated by many writers from the sixteenth century onward, the bibliography of the subject being voluminous. In addressing the Geologists' Association, I trust that I shall be pardoned if I give only a *résumé* of the historical facts most important for our consideration.

The Marsh is enclosed by an amphitheatre of hills, more especially on the north-east, where, from the top of the escarpment of the Lower Greensand, we may look down upon a level plain, the south side of which is washed by the sea. From the west and north of this plain the hills extend to the Wealden area, and give rise to the rivers whose waters brought down the sediment which has formed the delta. The largest of these rivers, the Rother, comes from the area of the great Wealden Forest, some 700 to 800 feet above O.D. The rocks through which the Rother, Tillingham, and Brede flow consist of the Hastings Beds.

If we descend to the Marsh, we find the soil is for the most part a rich alluvium, very favourable for grazing purposes. It is drained by numerous ditches, which empty their waters into streams called "Guts." Near Appledore Dowles large trunks of trees or moor-logs are met with, some of which appear to have grown on the spot, although they are found in the lowest land. Hasted states that the Dowles are about two miles long and more than a mile wide, one part hardly ever free from water, except in dry summers, and that there is strong evidence that they were

once covered with wood. I have noticed that some of the trees (which, I think, are willow) appear to have been cut with an axe. In other parts of the Marsh similar trunks of trees have been met with. I have also seen in the Dowles the remains of piles driven in the soil supporting the walls which surround that area, evidently so placed when the Poulder* was made. The ancient name for the place is Atpoldre or Appledore.

In the Geological Survey *Memoir*, p. 15, it is stated that “when peat is at the surface there is generally clay below at a depth of five or six feet, perhaps. . . . Sometimes, in clearing the dykes, the workmen come upon a layer of beach pebbles. . . . Whatever the soil may be near the surface, it is almost invariably the case that at a depth of ten or twenty feet there is loose sand, often containing recent marine shells, especially cockles. . . . The bottom of this is seldom reached in any well-sinking. . . . Mr. Elliott tells me he bored seventy feet in the Marsh, of which the last fifty were in sand.” I contend, however, that this does not prove anything, since the sand probably belonged to the Hastings Beds. Unfortunately, Mr. Drew neither gives detailed information about this boring nor does he state where it was put down. In a memoir on “Romney Marsh Past and Present,” read before the Surveyors’ Institute in 1885, Mr. A. J. Burrows states that the “Marsh is covered by a rich marine deposit, which boring has shown to be ninety feet in thickness near Appledore.” But here again we have no further information, if, indeed, the boring here mentioned is not the same alluded to by Mr. Drew, with the seventy feet magnified to ninety. We have one boring in the Marsh, viz., that at the Holmestone Camp at Lydd, made in 1886, which gives us the following details :

BORING AT HOLMESTONE CAMP, LYDD, 1886.

					Thickness.		Depth.	
					ft.	in.	ft.	in.
Recent	{	Shingle ...	...	...	15	0	15	0
		Boulders ...	...	...	4	0	19	0
		Brown Sand ...	...	...	13	0	32	0
		Clay ...	...	...	4	0	36	0
		Black and grey Sand ...	...	...	20	0	56	0
		Pebbles ...	...	...	1	0	57	0
Hastings Beds.	{	Black and grey Sand ...	...	...	58	0	115	0
		Stiff Loam ...	...	...	1	8	116	8
		Clean sharp Sand ...	...	...	4	4	121	0
		Loamy Clay ...	...	...	5	0	126	0
		Sand ...	...	...	2	0	128	0
		Clay ...	...	...	2	6	130	6
		Silver-grey Band ...	...	...	0	9	131	3
		Sandy Loam ...	...	...	2	3	133	6
		Clay Loam ...	...	...	8	0	141	6
		Strong Clay ...	...	...	5	6	147	0
		Stones ...	...	...	3	0	150	0

This boring was carried down, in similar beds, to a depth of 402 f inches.—See W. Whitaker, *Quart. Journ. Geol. Soc.*, vol. xliii, p. 204.

* A Flemish term for land reclaimed by means of embankments.

According to this, there were alternations of shingle, boulders, clay, and sand, of which only the upper fifty-seven feet are classed by the Survey Geologists as probably Recent. At Holmestone, where this boring was made, we should expect to find a larger amount of Recent deposits, since it is upon the beach contiguous to the sea and at a place where we learn a river formerly flowed. It is not at all clear what the thickness of these Recent deposits really is, and further information is required. Up the valley of the Rother there appears to have been a considerable deposit of silt and sand classed as sea-sand.

One of the great features of the Marsh is the Beaches, and in the Survey *Memoir* these have been carefully noticed. The great Denge Marsh Beach is one of the most remarkable of its kind in England, and its rapid growth around the Ness is especially remarkable. This beach maps out its own progress and direction by the manner in which it accumulates in ridges, dependent on the high tides; the ridges being carried up at full and new moon. When the shore line is stationary each succeeding tide obliterates the ridges of the former tides; but when the shore is encroaching on the sea, as is the case at Dengeness, each ridge being left, a succession of "fulls" will be seen marking its progress. Part of the Denge Marsh Beach is of earlier date, and differs in its direction from that at present forming, and is known by the name of the Holmestone. The ridges of this beach run inland towards Lydd, and must at one time have extended much further seaward. At the present time it is being cut back, and the beach stones carried on swell the volume of Dengeness. Mr. Drew has noted that the Holmestone Beach is apparently at a lower level than those now being formed.

The Denge Beach and the Holmestone Beach occupy an area three miles in length, with a breadth of from one to three miles, hundreds of acres being almost without vegetation. The point of the beach at Dengeness is constantly growing outwards and seawards; while east of the point it trends round in a curve, which is well illustrated in Mr. Drew's *Memoir* on page 17. The beach seems to have increased most near the Lighthouse, and, according to Mr. Drew and Mr. Redman, the average annual increase during the last two centuries has amounted to nearly six yards.

At Hythe another beach occurs, and from the "fulls" of this beach (which trend inland, and are abruptly cut off by the present shore-line) we may conclude that they formerly extended further seaward, like the ancient Holmestone Beach. At the present time there is no accumulation of beach at Hythe; but on the contrary, the shingle is being rapidly carried away north-eastward.

Between the Hythe Beach and New Romney the shore is destitute of beach, and a wall is maintained at a great annual expense to protect the Marsh from inundation by the sea.

Blown Sand is met with between Rye and Lydd on the land-side of the beaches; Blown Sand also occurs near New Romney, and a patch is to be seen near West Hythe on the land side of the present beach. These beaches and sand-hills form a natural protection to the land, which, being below the level of the sea at high tides, would otherwise be flooded. The sand-hills appear to have been formed at a period before the accumulation of the beaches had commenced, since the beach effectually stops the formation of sand-hills. We may connect these sand-hills by a hypothetical line extending from Rye to Hythe.

Having described the Marsh and the soils that compose it (which are of comparatively recent date), we will now discuss the numerous theories which have been brought forward to account for the way in which this delta was formed, and give some of the historical evidences in relation to the reclamation of the Marsh, and the changes in the river courses.

First, I should like to direct attention to a theory which seems to have been widely accepted by Archæologists and others who have written on the history of the Marsh. This theory, if not actually invented by Mr. Elliott, the engineer of the Marsh, was elaborated by him in a series of papers written about the year 1852. The first paper was written to assist Mr. Lewin (who wrote an essay to prove that it was here that Julius Cæsar first landed), and his theory was printed with Mr Roach Smith's "History of further Excavations and History of the Roman Castrum at Lympe." I must draw particular attention to this, because up to the time when I first wrote on the subject it seems to have formed the groundwork of nearly all that had been written on the district, even including the Geological Survey *Memoir* of 1864.

Mr. Elliott gave two maps of the Marsh, the first showing what he supposed it was like during the early part of the Roman occupation of Britain, and the second map to show what the Marsh was like at the time of the departure of the Romans, A.D. 480. According to Mr. Elliott, at, or about the time of the first advent of the Romans, the river Rother, then called the Limen, had its mouth in a large estuary near Appledore and flowed at the foot of the hills to Hythe, near which place the Romans erected the Castrum of Lympe; while another estuary, at Rye, received the waters of the Rother south of the Isle of Oxney, and of the Tillingham and Brede. According to this theory the deposits from these rivers had formed an oblong island, and it was supposed that the inward trending of the beach at Hythe marked the northern mouth of this estuary, that a spit or shingle bank was thrown off near Fairlight, and extended in a direct line to near Hythe; and that this shingle bank arrested the flow of the *débris* from the hills, and thus the dry land would first appear by the coast line from Rye to Hythe. The water would in this case recede towards the hills. It was this recession of the

water towards the hills that gave rise to the mystery of the river Limen, and the Roman station called Portus Lemanis. Then the shingle accumulating near Hythe, where this estuary emptied itself into the sea, gradually shut out the water and rendered the Portus Lemanis difficult of access. The Romans erected a great embankment from Appledore to Romney, and cut a new channel for the waters of the Rother to flow out south of this embankment to Romney; thus reclaiming the whole of Romney Marsh proper, consisting of about 24,000 acres. The Portus Lemanis was situate on an estuary at Lympne, and Romney became the Portus Novus of Ptolemy.

I must now refer to the Geological Survey *Memoir* on the Marsh, which gives copious reasons against adopting such an hypothesis, and yet ends by endorsing it. In fact, there are many false inferences drawn from the physical facts stated, chiefly, I believe, because the author of the Memoir had been told that the historical evidences proved the correctness of Mr. Elliott's theory.

On page 21 we read, "Judging from the size of the Rhee Wall it seems probable that the river gradually raised its bed by depositing sediment, the banks being heightened in proportion, till at last even the river bottom came to be as high as the land on each side." And we find that the river that ran out at Romney has forsaken its channel, as I shall presently show. Further, we read in the Memoir, "Where this Rhee Wall bounds Appledore Dowls, there is a good instance of what occurs in many places on the Marsh, viz., a difference of level between two parts; the lower one ending against an abrupt slope or bank that bounds the higher. On the south the fields are about the same level as the road [wall], while on the north there is a fall of many feet to the low ground of the Dowls; and the reason of this is that when the land is once enclosed and kept from the influence of the sea, it gets no further sediment deposited on it, but keeps the same level, while that outside is always receiving fresh accessions of mud, etc., which raise its level, sometimes even, in a long course of time, to nearly the top of the wall that was made to keep out the sea from the first tract. Therefore the older the enclosure is the lower the land." But the author of the essay on page 20 writes, "*I have stated that the Rother, then called the Limen, used to flow out at Hythe.*" No physical causes are quoted to show that the river flowed out at Hythe, but it seems that it was because Canon Jenkins told Mr. Drew that there were Saxon Charters to prove it. Then one Charter is quoted, which, instead of proving this statement, makes it clear that at that time there was no such river flowing near the hills at Hythe. I will give you the undisputed historical facts, as briefly as possible.

In early Roman times there was a southern port on the Kent coast known as Portus Lemanis, also a river called the Limene

The first mention of this is in the "Itinerary" of Antoninus, who gives the distances by the roads from the Roman military stations and towns. In this "Itinerary" Portus Lemanis is placed at some distance from Lemanis. Mr. Roach Smith estimates the distance at ten miles. Somner, who wrote an essay on the "Roman Ports and Forts" in 1660, places Lemanis at New Romney. The later Roman writers do not mention Portus Lemanis, but only Lemanis. The Roman Castrum of Lemanis, now called Stutfall Castle, was erected during the later period of the Roman occupation of Britain to repel the invasions of the Saxons ; and apparently after the station Portus Lemanis had become in some way changed or destroyed, for built into the walls of the Castrum was found an altar with inscription and inscribed tiles, presumably taken from the Portus Lemanis, the altar stone having barnacles attached to it as if it had been in the sea. Therefore, the present Castrum proves nothing with regard to the former Limen port.

The Saxon Charters of the seventh and eighth centuries are all quoted by Somner to prove that the Limen was at Romney. But especial mention is made of one relating to a piece of land at Sandtun, that was bounded on the south by the river Limen, and which Mr. Mackeson identifies as a place called Sandtun, where there is a patch of Blown Sand.* The charter proves that the river Limen flowed south of Sandtun, and yet is quoted to show that the river flowed to the north of that place, by West Hythe and then on to Hythe. I have been told that this charter shows that the Limen river flowed then much nearer Sandtun than the position of the Rother at New Romney would indicate. Nevertheless, it upsets the whole theory that the Hythe beach proves the gradual filling up of the mouth of the river by successive ridges formed at the mouth of the harbour, for in that case the mouth of the river or estuary must have been pushed near up to the hills at West Hythe. The other Saxon Charters prove that land existed at Bishop's Wick, close to Romney, and do not help the theory at all.

In the ninth century, according to the Saxon Chronicle, a fleet of 250 Danish ships was towed up the Limen beyond Appledore, where a landing was effected and a fort destroyed. Now, could these 250 Danish ships have been towed up the river that emptied itself at Hythe 300 years after the Romans had quitted the county ? and, if so, what becomes of the theory that all the Romney Marsh had been reclaimed from the sea by the erection of the Rhee Wall ? We must, perforce, admit that in the ninth century the river up which the Danish fleet sailed, or was towed,

* The charter gives the boundaries of this Sandtun Land as : South by the River Limena : north and west by the Hudan Fleot ; east by the King's Land. Hudan Fleot Mr. Wilks identifies with the stream that rises in the Greensand near the Castrum and flows close to the hills to Hythe, and is referred to in ancient documents as the "Slows" which emptied its waters into Hythe Haven.

was the river that flowed out at Romney, then called the Limen.

Now with regard to this river that had so raised its banks, as the author of the *Memoir* pointed out. Are we to look for the ancient Limen river close to the hills between Appledore and Hythe, where we find the lowest land, and no physical evidence that the river even flowed there at all? or, do not all the physical and historical facts point to the conclusion that the ancient river was at Romney. We know that New Romney was one of the Cinque Ports at a very early period; its importance was due to the fact that it had a harbour and an important river. It flourished especially as a port in the tenth century. According to Mr. Elliott and several other writers, it was the Portus Novus of Ptolemy, in which case it must date back to A.D. 125 or 140. But in the thirteenth century, owing to some coast alterations and fearful storms, the river entirely forsook its old channel from Appledore to New Romney, in spite of the stupendous efforts made by the inhabitants in the previous years to keep the water-way open by deepening the channel. It is probable that the gradual decay of this haven had been going on for some time. Very interesting information respecting the town and port of New Romney is to be found in the thirteenth volume of the *Kent Archaeological Society's Proceedings*, from the essays of Canon Scott Robertson, Mr. R. Furley, and Mr. Walker. Mr. Furley has written a memoir on the Marsh, and given the particulars of all the "innings" or reclamations of land south of the Rhee Wall. I have copied these particulars on the map (Plate IX). Canon Scott Robertson has shown in a map of the Cinque Port Liberty of New Romney that it extended beyond Appledore into the north-west branch of the river Rother, round the Isle of Oxney; it was, in fact the dry channel of the river that had, in the thirteenth century, forsaken its course.

In 1822 a very ancient vessel was found buried in the Rother channel north of the Isle of Oxney, a description of which was communicated to the Society of Antiquaries by Mr. Thurston Rice, L.S.A., from which it appears that the vessel was wrecked in the channel, and had been buried to a depth of ten feet with silt since accumulated. And also that at that time the larger river valley of the Rother, south of the Isle of Oxney, was barred by embankments. In reference to these walls Mr. Furley writes: "In the early part of the sixteenth century the valley of the Rother south of the Isle of Oxney was barred by a wall from Wittersham to the mainland on the opposite side of the valley, and is now known as Blackwall; the effect being that the waters of the Rother were forced to take the upper course; so prior to 1287 the lower valley became of secondary importance."

The fact that the river which ran out at New Romney altered its course to Rye, in consequence of some great storms, by

breaking through the shingle beach that old Winchelsea was built upon is disputed, and probably one outlet of the Rother and Brede waters had always been at Rye. At any rate it is clear, as Mr. Furley has stated, that during the 200 years succeeding the Norman Conquest the Walland Marsh had been gradually getting above the level of high water, and many hundreds of acres were reclaimed. Before the Norman Conquest this marsh must have been a dreary waste of mud-banks and water.

One other fact has been used as an argument in favour of the Limen river having flowed out at Hythe, viz., that just above Lympne Castrum there is a place called the Shipway Cross, where great and important meetings were held. Leland (I think) says: "Shipway Cross was so called because it lay on the way to the haven where ships were wont to ride." At this place in former times were held the great assemblies relating to the Cinque Ports and here the Lord Warden received the Oaths of his Vassals. Prince Edward, son of King Henry III, received here from the Barons of the Cinque Ports their Oaths of fidelity to his father. It seems, however, to have been merely a neutral ground where the Court of the Barons of the Cinque Ports was held, before the Court was moved to Dover. These Cinque Ports were very jealous of each other's privileges, therefore this neutral ground seems to have been selected.

But to return to Romney Marsh proper. North of the Rhee Wall, we find that it had been extensively occupied in Roman times; and near Dymchurch, where the sea-wall is erected, it must have been protected from inundation by the sea from the east and south, as Roman potteries have been found in the Marsh at that place close to the sea, that could not have existed had there been no barrier to the sea in this direction.

Having placed before you the facts relating to the physical and historical evidences of Romney Marsh, I will sum up with my own inferences in respect to the origin of this delta. Or rather, let us see how the present configuration of the Marsh has been brought about. Although I have termed it a delta, it differs in many important respects from the deltas of other rivers, inasmuch as the land rises towards the sea and falls towards the high lands that bound it on the north and west, and with the exception of the point of Dengeness, it has not encroached upon the sea, but rather the evidence points to the land having at one time extended farther seawards.

We may take it, then, that the first stage in the process was the filling up of a depression in the older formations (which depression must have presented the appearance of a shallow bay) by deposits brought down by the rivers Rother, Tillingham, and Brede, which discharge their waters into the south-western and western half of the Marsh. We should therefore expect that

the silt would settle and fill up the northern half of the bay, as we find was the case, for the Romney Marsh proper was the first to be inhabited, and we may be sure also that this took place before the coming of the Romans. The presence of high banks on either side of the river that flowed out in early times at New Romney points to the conclusion (as indeed Mr. Drew shows) that it was the natural course of the river, or of one of the rivers, flowing out at this place, and, as we found from later historical evidences, the river so raised its bed by the deposit of silt that at last the waters were compelled to find a fresh and more westerly outlet to the sea. In the geological map of the Marsh a probable line of fault is indicated between Appledore and the Isle of Oxney and Ebony, which may in the first instance have determined the course of the rivers. If in addition to this, the chief direction of the ocean-currents was from south towards the north, there would be additional reason to conclude that the earliest deposit must have been towards the north. I therefore dispute a notion that the earlier exit of the waters of the Rother was from Appledore to Hythe, as has so often been stated.

Everyone agrees that the earliest reclaimed land in the Marsh was that at Appledore ; and it seems evident that the embankment raised to protect the Marsh then was part of the Rhee Wall, and from Snargate it extended to Warehorn. By the Saxon Charter we learn of grants of land in the fens of Warehorn having boundaries that extended southward over the Limen into the South Saxon limits ; and we find the rain water from these fen lands was pumped up and discharged into the river that ran south of the Rhee Wall. But we have already shown that none of the historical evidences quoted show that any river ran along this side of the Marsh to Hythe.

During the earlier stages of the silting up of the Marsh we learn from the *Survey Memoir* that sea sand, cockles, and at places beach pebbles, are met with under the Alluvium, but there appears to have been no great shingle banks at that time to keep out the sea. We have evidence that somewhat later Blown Sand or sand-hills existed. These hills in part remain ; one patch may be seen behind the beach at Hythe, at the place indicated in the Saxon Charter of Sandtun, which barred the entrance of the sea to the Marsh in this direction. We may conclude that the sand-hills north of Romney acted in the same manner, also those south of Romney and Lydd.

The next stage in the progress of the Marsh was the accumulation of beaches. Some of these are of more ancient date than the others ; one, for instance, south of Lydd known as the Holmestone. The Holmestone Beach existed at the earliest date of which we have historical record. It differs in height and direction from the later beaches, and covers up mud and peat of some earlier land that extended further seaward. This

beach has been, and is being, cut off abruptly by the shoreline. It may have extended as the lines given in the Geological Survey map indicate, forming a barrier opposite Rye Harbour. Probably considerable changes were taking place in the direction of the ocean currents at the time when these beaches were being formed.

I demur to the general statement that the accumulation of sea beaches is entirely due to the prevailing winds. If so we should find them trend in one direction, whereas I have noted on the Kent coast that, while on the south the direction of the beach was from south-west to north-east, on the northern part of the coast the direction of the beach was directly opposite, viz., from north-east to south-west. Along this Romney coast we find the Dengeness Beach accumulating round a point more to the north than the Holmestone Beach, showing a change in the currents of the sea. At Hythe we find another beach which is now being cut back by the shore-currents. Further, we find many similar cases along the south coast of England. Knowing that the Romans founded settlements in the Romney Marsh, and that at Dymchurch close to the sea they had potteries, we must conclude that either sand-hills or a beach existed there at that time to protect the Marsh. I think the present beach at Hythe is the remnant of such a beach; and if we compare the trending inland of the tail of the beach, it points to the conclusion that some promontory formerly existed between Romney and Hythe, so the trending of the beach will not favour the conclusion that a mouth of a river or estuary existed at Hythe; nay, it points to the conclusion we had arrived at from the study of other causes, viz., that the ancient Limen ran out at Romney, and the exit waters there had much to do with the retardation of the beach; the same may be the case at Denge Point.

Before leaving the subject of the changes indicated by the beaches, I should like to draw attention to the height of the Holmestone Beach compared with Dengeness Beach, and also to the evidences of the peat or bog-oak and trees, as pointing to some fluctuations in the level of the land. Apart from the Marsh, along the south coast of England and the neighbouring coast of France and Holland, we have evidence of a former depression when sea-beaches were formed, followed by a re-elevation of the land, on which trees sprang up and flourished, while, again, in the buried forests we have the proof of another depression. It has been suggested that the trees buried in the Marsh, and those at Appledore, belong to the same period as the submerged forests of Hastings and elsewhere on the South Coast. And I think this is very likely to be the case. It does not follow that the trees had all grown on land at one level; some found in bays may have grown on higher ground. In parts of the Marsh, Appledore for instance, these trees are merely covered with

the peaty soil of the marsh, while those near Rye seem to have been covered with a considerable amount of silt. Mr. Godwin Austen, in a paper read before the Geological Society in 1851, drew attention to the changes on the coast of the English Channel (*Quart. Journ.*, vol. vii, p. 118). He states, "The communications on the present subject have generally been noticed under the head of raised beaches, they have been invariably considered as illustrating the vertical movements of the earth's crust as referable to one single period of time, and my object will be to show that the phenomena are more complicated. That they imply *a vast period of time, and that one* most important character has been entirely overlooked." Mr. Elliott, in the Memoir before alluded to, supposed the trees in the Dowles to have been drifted there by the waters of the Rother; but in that case we should expect them to have been covered with mud or silt, which does not occur to any extent. Altogether the evidences are in favour of some change in the relative height of the land compared with the sea.

Another question suggests itself. Did any change of level occur after the Roman occupation of the Marsh? It is very commonly supposed that when the Romans visited this country, the land stood at a lower level than at present. I have lately been investigating the matter in respect to parts of East Kent, such as the neighbourhood of Richborough, Reculvers, and the Swale marshes at Sittingbourne; in every case there would seem to have been a depression of the land since the Roman occupation, say since the fifth century. M. Gosselet,* in describing the changes which had taken place in plains extending from St. Omer to Dunkerque and to Calais, stated that the Romans had occupied the entire area; then there had been an invasion of the sea which covered the relics of the Roman occupation with sand. The sea left the area, which then became covered with vegetation, and afterwards Flemish towns were erected over the area formerly occupied by the Romans. I do not think we have a similar case on our Kentish shores; but we have evidence of a slight variation in the level of the land.

Historians have been busy with speculations respecting the rivers in the Marsh. According to them the rivers were very fickle, changing from Hythe to Romney and again from Romney to Rye, but the only changes that I know of may all be accounted for by the shifting of the beaches.

As to the rate of alluvial deposit we have some important facts; first, it seems that an ancient vessel, which had been wrecked about the twelfth century in that branch of the Rother which ran north of the Isle of Oxney, had, when found, been covered with a deposit of alluvial mud to a depth of 10 feet;

* *Revue Scientifique*, p. 90, 1878.

and by the fifteenth century the river in which the vessel was found had forsaken its course for one south of the island. Formerly this southern branch of the river had been stopped by artificial barriers, which compelled the waters to keep to the northern channel ; this dam seems to have been entirely removed in 1635, and since that time the river has always taken the southern direction to Rye. The innings of the lands south of the old Rhee Wall are dated 774, 1162, 1270, and 1339.

We have also some data for the rate of growth of the beach at Dengeness, which, according to Mr. Redman's calculation, has an annual growth of six yards ; at this rate the beach must have taken fourteen hundred years to attain its present dimensions.

We require more information respecting the depth of the Alluvium of the Marsh, and the underlying strata. The statement that the borings in the Marsh near Appledore showed 70 feet of alluvial deposit requires confirmation ; it is just there that we might expect to meet with Hastings Beds in the subsoil which, as I have before stated, might be easily mistaken for Recent deposits, they being composed of alternations of clay and sand. Near the escarpment at Hythe we know very little about the underlying Wealden beds. We want more information respecting the peat beds of the Marsh and their contents, especially the extent of the buried forest ; also, concerning the trees of the Dowles. There are many other problems in this interesting district which require further working out.

The sequence of changes in the Marsh may be summarised as follows :

Firstly, a shallow bay existed in a depression in the underlying rocks. Into this bay the waters of the Rother, Tillingham, and Brede, on the way to their outlet near Romney, deposited their silt, so that the northern half of the Marsh had become dry land previous to the time of the Romans.

Around this bay were formed sand-hills.

In time of flood the waters of the river that ran out at Romney overflowed, and, depositing silt, raised the banks on either side.

A slight depression of the land commenced, and has continued.

Beaches accumulated, especially between Romney and Hythe, and between Romney and Winchelsea. Romney probably formed a promontory at Dymchurch, near where the ancient river, then called the Limen, discharged its waters. The Limen had, by the twelfth century, changed its direction so as to impede the outflow of the rivers at Romney, and to enlarge its mouth at Rye. Finally, in the thirteenth century, from this cause and the raising of the river bed by silt, the Romney River entirely forsook its channel, and has since flowed out at Rye.

The Rhee Wall was, in the first place, a natural river-bank, subsequently raised and altered by the Barons of the Cinque Port of Romney.

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ON THE GEOLOGY OF THE STORT VALLEY (HERTS AND ESSEX) WITH SPECIAL REFERENCE TO THE PLATEAU GRAVELS.

BY THE REV. DR. A. IRVING, B.A., F.G.S.

[Read 3rd December, 1897.]

THE two most interesting factors of the stratigraphy of Stort Valley are (i) the deep erosion of the Chalk along Stort Channel, proved to a depth of 190 ft., and now for most part filled with detritus; (ii) the Stratified Gravels, a succession probably of river-deposits, giving us indications of work that was going on in our British Area during the period represented by the "Neogene" (=Miocene + Pliocene) of Continental Geologists. The two must be studied together, evidence which each offers supplementing that of the other as the geologic time represented.

This paper must be understood as supplementary to Report of the Excursion on July 17th, 1897, published in PROCEEDINGS of the Association, vol. xv, part 5 (Nov., 1897). What, therefore, is sufficiently stated in that Report will not be here repeated. A few notes are appended bearing on the points touched upon in the Report in connection with the Chalk, the overlying sandy deposits, and the Pebbly Conglomerates.

The Ancient Stort Channel.—In addition to the facts mentioned in the Report, some further details are here supplied. A list of wells sunk through the detritus which now fills the channel in the Chalk for the most part, and showing in each case the depth at which the Chalk is reached, has been kindly furnished to me by Mr. G. Ingold, well-sinker of Bishop's Stortford, as follows:

								Feet.
Railway station	...	...	...	...	Chalk reached at			55
Gas-works	...	...	...	...	"	"		135
Anchor Maltings	...	...	...	...	"	"		135
New Town Malting	...	...	...	...	"	"		50
South Street Malting	...	...	...	...	"	"		91
Mineral-water works	...	...	...	...	"	"		144
South Mill Malting	...	...	...	...	"	"		40
Twyford House	...	...	...	...	"	"		61
Twyford Bury	...	...	...	...	"	"		120
New Malting in South Road	...	...	...	...	"	"		170

The details of the last well executed at the New Maltings South Road are as follows:

								Feet.
1. Made ground	5
2. Gravel	1
3. Small Gravel and yellow Sand	20
4. Grey Clay	1

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								Feet.
5.	Grey sandy Gravel	2
6.	Blue sandy Gravel	2
7.	Blue Clay	3
8.	Brown peaty Clay	31
9.	Blue sandy Clay	...	...	...	...	...	...	3
10.	Grey Sand, Shingle, and Stones	...	...	...	...	...	...	30
11.	Yellow and grey Sand and Shingle	...	...	...	...	...	...	10
12.	Grey Sand and Shingle	...	...	...	...	...	...	16
13.	Blue Clay	...	...	...	...	...	...	3
14.	Dark grey Sand	...	...	...	...	...	...	17
15.	Brown Sand	...	...	...	...	...	...	1
16.	Yellow Sand and loamy layers	...	...	...	...	...	...	15
17.	Clay and Stones	...	...	...	...	...	...	10
								<hr/>
								170
	Chalk with flints	...	...	...	...	...	...	55
								<hr/>
	Depth of well	...	...	...	...	...	...	225

What in reality are these deposits? There is no evidence from the boring (since the materials were not brought up in cores) to help us as to their stratification. Are they then of Quaternary or pre-Quaternary age? Or are they recent alluvium, mere down-wash from the adjacent *terrain*? The choice of these alternatives affects immensely their value as evidence of the *age of the channel of erosion in the Chalk*, and upon this hangs, as we shall see, to a large extent the age of the Stratified Gravels. Some light is thrown upon this as we work northwards up the ancient channel. To do this, we must leave the line of the present Upper Stort river, which rises above Clavering, and follow the line of the Great Eastern Railway up to the present watershed between the drainage of the Stort and that of the Cam at Elsenham. Close to Stanstead Station a gravel-pit has been recently opened, and is worked by the side of the railway. Here about 15 feet of a sandy gravel are worked. The gravel is distinctly stratified, with pronounced false-bedding, surmounted by some 20 feet of angular flinty material, very irony, quite unstratified, an unquestionable *glacial* deposit. The stratified gravel rests on an uneven surface of a "white clay" with flints, which appears to be reconstructed half-decalcified Chalk material. The stratified gravel, of Quaternary age at the latest, may correspond very well with the 20 feet of "small gravel and yellow sand" (No. 3) in the well-section; and the underlying white-clay with flints may possibly represent the 10 feet of "clay and stones" (No. 17) of that section, the intermediate beds being wanting in the Stansted section, either from the latter being higher up the old valley or on the valley-flank. This valley is truncated by the Elsenham Gap in the Chalk range, to the north of which we enter upon the valley of the Cam, referred to in the Report of the Excursion, also a buried valley, as described by W. Whitaker (see Report for reference to his paper).

Close to Elsenham Station, and almost on the very watershed of the district, a well has recently (October, 1897) been bored by Mr. Ingold. The mouth of this well is 300 feet above O.D., and it pierces 90 feet of what Mr. Ingold describes as a flinty gravel before the Chalk is reached. It is probably in the main mere flinty residuum of the Chalk of the neighbouring hills, such as one sees exposed in the cuttings near the ends of the tunnels which pierce the Chalk hills on the Great Northern and Midland Railways. Rubbly Chalk material was brought up from the lower portion, and in this I found, in addition to the flints, stray pebbles of Chalk, Millstone Grit, and Carboniferous Limestone, the last two varieties of rock being no doubt brought down from the plateau-gravels at a higher level, along with the flinty stuff, the degradation of the hills having been aided by glacial agencies. The Stort-Cam watershed about Elsenham may therefore date from the Glacial Period. A little reflection will show that if we deduct (at least) 90 feet from its altitude, we get down to a level for the ancient channel in the Chalk, which requires no very steep gradient to correlate it with the channel, whose depth is known at Bishop's Stortford. The head-waters of the Cam no doubt represent some reversal of drainage since Tertiary times.* If we take the data to hand, and calculate the gradient of the ancient channel, from 200 ft. O.D. at Elsenham, to 0 ft. O.D. (or thereabouts) at Bishop's Stortford, we get a result which gives much less than 1° . And the question arises as to the correlation of this with the ancient channel of the Lea between Broxbourne and the Thames. Evidence on this point might lead to some further interesting conclusions.

THE STRATIFIED (HIGH-LEVEL) GRAVELS.

These present us with the most knotty point of the geology of the district under consideration (see "Report of Excursion").

In the extensive gravel-pit at Thorley there is no trace of a "passage" between the gravels and the overlying Boulder Clay. To look upon the gravels there exposed as in any way subordinated to the Boulder Clay seems out of the question. They represent a totally different set of conditions of deposition. It is very difficult to regard them as in any sense "inter-Glacial." Everything in their structure and arrangement shows them to be fluvial deposits, mere portions of wider spreads of river-shingle, along the lower course (*Unterlauf*) of a river, the current of which, losing a portion of its force by the lessening of its gradient, has deposited

* Comp. A. V. Jennings, F.G.S., "On the structure of the Davos Valley," *Abs. of Proc. Geol. Soc.* for Jan. 5th, 1898, and Mr. Harmer's reference (*l. c.*) to the watershed of the Waveney and the little Ouse. I have referred in former papers to a similar reversal of drainage by glacial detritus at the Pass of Manrach at the south end of the Achensee in North Tyrol, which I had good opportunities for studying some years ago.]

materials, which with the higher gradient of its middle course (*Mittelauß*), it was able to drive along its channel.* Observation of sub-Alpine rivers shows that the gradient needed for a river to be able thus (especially in times of flood) to keep its channel in its middle course pretty free from the detritus brought down from its head-water regions (*Sammelgebiet* or *Oberlauf*) is not very great. In my paper in the *Geological Magazine* of May, 1893, "On Post-Eocene Surface-Changes in the London Basin," I have shown how we may rationally comprise gravels of the Southern Drift to the south of the Thames, lying at varying altitudes in the Plateau-Gravel series; and the same argument, I conceive, applies (*mutatis mutandis*) to the Plateau-Gravels of Herts and North Essex. Here we have to do, however, with materials of the *Northern and Mercian Drift*, mainly the latter, as the composition of the gravels indicates. There are few sub-angular and discoloured flints in them, instead of a preponderance, as we find in those of the Southern Drift on the south of the Thames; fragments of Neocomian chert seem to be wanting; while flint pebbles are numerous, as are also, in these gravels, pebbles (large and small) of quartz and quartzite (white, pink, and liver-coloured), and even rolled fragments of the crystalline rocks.

Some of these quartzite pebbles are of fair size, and being exceedingly tough are thrown aside in the pits for use as "setting-stones" for rough paving work in the neighbourhood. They have the same lithological character as the well-known quartzite pebbles of the Midlands (e.g., at Sutton Coldfield) and of the Devon Bunter (Budleigh Salterton and Aylesbear Hill†), which often contain casts of Silurian fossils. These larger pebbles are found *at the bottom of the gravel*, along with sub-angular blocks of sarsen-stone (the wreckage probably of later Eocene or Oligocene strata of the Tamisian area), occasional well-rolled masses of Millstone-Grit, and sub-angular blocks or pebbles of vein-quartz. Their occurrence at the base of the gravels tells of the maximum of driving power (when its gradient was highest) of the river, which brought them to their present position, the driving power diminishing as that gradient diminished, with the lowering by denudation and crust-movements of the Mercian uplands, from whence the waters of the river came (to join those of the ancient Kennet-Thames valley‡). Their immediate source can only be found in the Bunter Sandstone of the Trias, and for this we have to look to the North and West Midlands, all the intermediate country being occupied by younger formations. These quartzite pebbles of small boulder dimensions seen lying in the Thorley Gravel-pit,

* Comp. Dr. Hermann Credner, "Elemente der Geologie" (Prozess der Thalbildung), pp. 238—241 (6th Ed., Leipzig), who adopts these terms from Prof. Albert Heim of Zürich.

† Compare A. Irving, "On the Devon Red Rocks," *Quart. Journ. Geol. Soc.*, vols. xlv and xlviii.

‡ See A. Irving, "On the Stratigraphy of the Bagshot Beds of the London Basin" (Part ii); *Quart. Journ. Geol. Soc.* for May, 1888.

are precisely the same as are picked off the fields for road-metal in the Trent country, where (as, *e.g.*, in the Leen Valley) the erosion of the Bunter has been carried by river action down to the Permian Marls.* I do not think that a complete collection of the Thorley pebbles (flints and sarsens excepted) would fail to be matched *seriatim* at Sutton Park near Birmingham. Fine sections of the stratified gravels are met with further up the ancient Stort Channel at Stansted, (a) off the Cambridge Road, (b) near the National Schools, (c) north of the Castle Mount. These gravels are overlain at each place by a *glacial* deposit, consisting of sand and weathered (mostly unworn) flints, taking the place of the Boulder Clay of some of the previous sections. The stratification of the river-gravels here has been flexured, as if from the local pressure here and there of pack-ice above. In all three sections well-rolled fragments of a *Gryphæa* are quite common in the *stratified gravels*; and the sand, which is abundant, is coarse and gritty, a true river sand, with very little iron investment of the grains. At the north end of the Thorley pit the stratified gravels are more disturbed, even puckered, as if pack-ice or raft-ice floating down from the north had stranded against the bluff of the hill.

Of the Stratified Gravels described in this paper, we may say :

1. It is tolerably certain that they were laid down by *rivers*, while the materials tell us that those rivers came from the Mercian region.

2. No rivers could possibly have laid them down on the brows and bluffs of the present hills, where we now find them, with the present surface contours.

3. They are proved to be of older date than the Boulder Clay and its equivalents by the superposition of the latter.

4. Their position with reference to the present *terrain* shows that they are of much older date than the present Stort drainage—

But (5) the Stort valley itself is probably of pre-Quaternary date, and the extent of its erosion interposes a long interval between the gravels and the Boulder Clay.

We may feel some confidence therefore in dating the deposition of these gravels far back into Tertiary time, probably the Miocene, the most probable account of them being that which regards them as *deposits of Mercian rivers of the great Miocene elevation of North-Western Europe*.

Some differential movements, doubtless, occurred over the East Anglian region, to let in the shallow waters of the sea, in which the Crag was deposited in Pliocene time over the eroded surface of the London Clay, filling in many cases its sub-aërial valleys on the more eastern side of the region; and as a counterpart to the subsidence there, it is possible that some

* A. Irving, "On the Geology of the Nottingham District," *Proc. Geol. Assoc.*, vol. iv.

corresponding axial elevation* on this more western side of the East Anglian region may account for the extensive erosion of the channels of the Cam and the Stort alluded to above.

It is, I think, a reasonable hypothesis, that as the counterpart to such a movement—a mere ripple-flexure of the crust as compared with the great movements, which took place on the Continent of Europe at the close of the Miocene age—some subsidence also took place a little further to the north; and that from this may date the cutting-through of the gap in the Chalk, in which the great estuary of the Wash now lies. This would give a Pliocene date for the eastward trend of all the present Mercian rivers south of the Trent, and fully account for the incidental pre-Quaternary excavation (in part at least) of the now-buried valley of the Cam, to which reference has been made above. If this were so, then an additional argument is furnished for dating back to the Miocene the deposition of our stratified plateau-gravels, laid down by Mercian rivers, cutting through the Chalk into the Tamisian area.

The late Sir Andrew Ramsay has pointed out† that “the Miocene Period of old Europe was essentially a continental one”; and his speculations (*loc. cit.*) led him to assign the southern flow of the Severn to differential movements of the Mercian area at the close of the Miocene period. The present writer ventures to go further, and to suggest a causal connection between that later Tertiary initiation of the present West-Midland Drainage, and the *great overthrust fault*, which brought up the Archæan Crystalline rocks along the Malvern and Wrekin line of elevation, with a corresponding underthrust of some thousands of feet of the Palæozoic Strata. The dislocation indicated by that fault is on a scale of sufficient magnitude to furnish all the data we want for Ramsay’s hypothesis; and, on the other hand, enables us to understand how, prior to the Malvern-Wrekin epeirogenic movement, rivers originating even in the Welsh Highlands could have flowed into the Tamisian area.

A week or so after this paper was read, I had occasion to visit Welwyn, which lies in the deep valley of the Mimram or Maran, and was struck with the precise similarity of the gravels there (at about 220 feet O.D.) to those of the Stort Valley. In the principal pit near the village we meet with good sections of the same stratified gravels, with Triassic *débris*, as we find hereabouts (Thorley, Stansted, etc.). The bottom of the gravel is not seen in the pit. Overlying the stratified gravel are 10 to 15 feet of unstratified flinty angular stuff, almost all flints, more or less weathered, but not rolled to any extent. The section is almost the exact counterpart to those at Stansted (*supra*). The head of the Valley of the

* In the *Mem. of the Geol. Survey*, on this district, two considerable anticlinals in the Chalk are figured. These seem to afford direct evidence of such an axis of elevation as is here postulated.

† *Phys. Geol. and Geog. of Gt. Britain*, p. 508, 5th ed.

length being the result of accidents of contour developed in later times, while the true parent-rivers, as shown by the antiquity of their valleys, are in the former case, the valley of the Mymra which is truncated by the Hitchin Gap, and in the latter case that which is truncated at the Elsenham Gap, and joins the modern Stort valley below Stansted. The main-line of the Great-Eastern Railway therefore follows the line of the pre-Quaternary channel.

Since this paper was read, I have had the pleasure of the perusal (with the accompanying map) of the interesting paper by Mr. H. J. Osborne White, F.G.S., published in the Association PROCEEDINGS (vol. xv, part 4). I am happy to find that my recent observations and the conclusions to which they lead here in the Lea-Stort country, harmonise with his, farther to the west. I should also add, that I think he has made out a good case for the pre-Quaternary initiation of the line of drainage since deepened into the Goring-Pangbourne Gap through the Chalk, and this is the more satisfactory, as it relieves one of some doubt, which I felt at the time, about suggesting the initiation of that valley by an overflow of an extra-morainic west Mercian lake. Mr. White's quotations from Professor Davis are to the point; but I can assure him that to those of us, who are familiar with the German literature of Geological Science, as represented by such excellent works as that of Professor Hermann Credner, of Leipsig, the ideas of Prof. Davis are not altogether new. The reading adopted in this paper of the history of these Stratified Gravels on the northern side of the Tamisian area harmonises with the view of himself and others as to the Southern Drift, and is corroborated by the writer's own observations last autumn of very fine new sections of a stratified terrace-gravel in the valley of the Trent, at Silver Hill, Beeston, near Nottingham. The gravel is shown in duplicate sections, and is about 40 feet above the present Trent river. There also it is easy to observe the decreasing coarseness of the materials, as one works up the section, the gravels passing upwards into beds of reconstructed Bunter sand. To such an extent are they made up of Bunter materials, that some of the Nottingham Geologists have mistaken them for Middle Bunter Pebble Beds; but the possibility of such an interpretation was soon seen by the writer to be excluded by the quite common occurrence in them of angular and sub-angular fragments of bleached flints from the Chalk. Their pre-Glacial age is shown by the superposition upon them of several feet of Glacial Drift, with large Bunter pebbles standing erect in the unstratified sand.

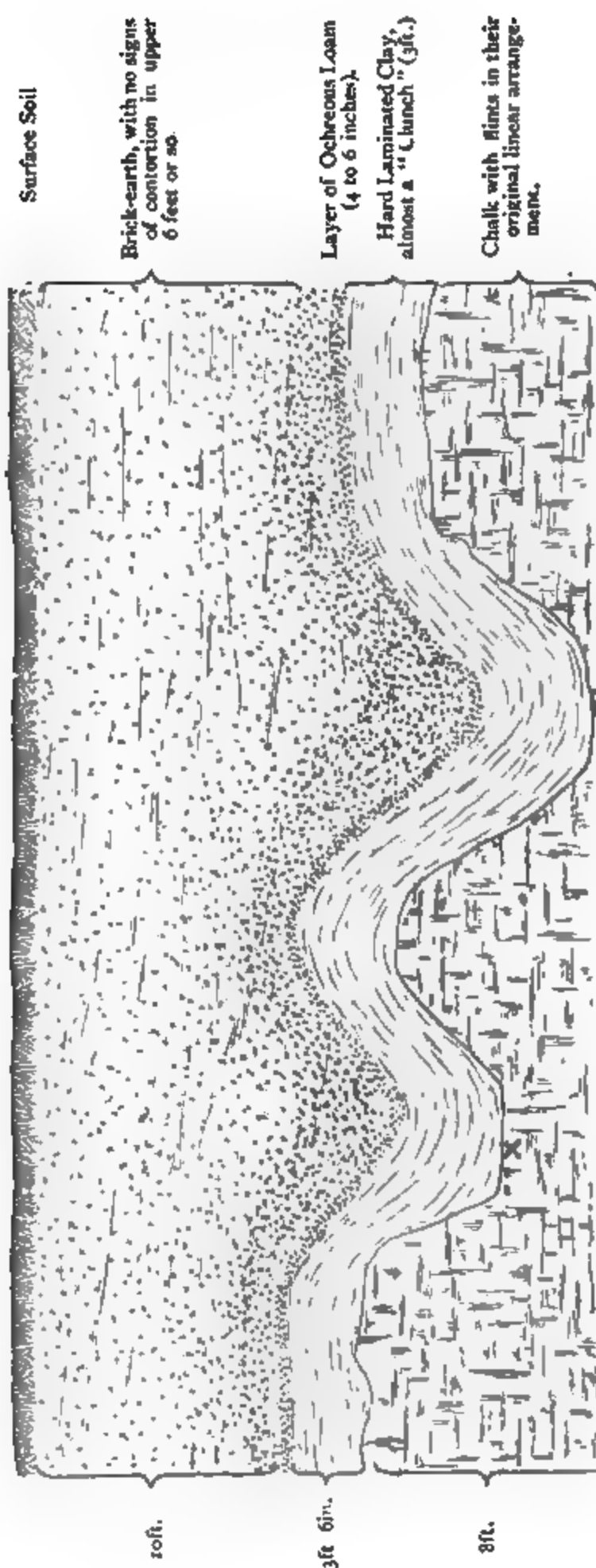
NOTE I.

The junction-plane of the Chalk and the Tertiaries.—That the Chalk has undergone some destruction is evident from the g

Quantity of large and small unrolled nodular flints at this horizon, as stated in the Report. In suggesting that this is due to marine abrasion, I have been perfectly aware of the theory put forward in vol. iv of the *Memoirs of the Geological Survey* many years ago (pp. 58, 59). In the discussion of this paper Mr. Whitaker reiterated that view, but advanced no fresh evidence in support of it. It was suggested that the removal of the chalk in solution by carbonated rain water might take place below the permanent water-line in the ground ; but, if that were so, we should expect to find the chalk cavernous and not merely planed down, and the actual amount of work done would be quite insignificant, because without free circulation of such waters the water in contact with the chalk would very soon have its small amount of free CO₂ fixed (in other words it would be chemically saturated), and solution would cease. Curiously the necessity for such free circulation of carbonated atmospheric water was recognised when the theory was propounded (*loc. cit.*). Again, though the permeable character of the Thanet Sands, as they overlie the Chalk (*e.g.*) in Pegwell Bay, may favour such a theory, it is very difficult of application where the strong clays of the Reading Beds rest upon the Chalk. Moreover, it is not quite true to say that "the flints never show any traces of having been rolled or worn by the action of water," for I have found green-coated flint pebbles in the basement bed of the Reading Beds here, and much more commonly at Reading. I may perhaps be allowed to add an unpublished note made in 1880 on a new pit-section in Coley Hill brickyards at Reading, as follows : "4 feet immediately above the Chalk include the Ostrea-bed and flints, also phosphatic nodules scattered more or less through the whole range of the bed. At about 3 feet from the base, a regular continuous layer of broken *O. bellovacina*. The clays above and below this glauconitic ; well-rounded pebbles dispersed through the bed. Surface of chalk very regular. For about 1 foot below present surface of the chalk, numerous small fissures and tubes lying in all directions, and at all angles, filled with glauconitic material." Upon the whole, I agree with Dr. Barrois,* that it is more probable that (as first suggested by Mr. Dowker), the facts observed are due to "the decomposition of the Chalk while it was emerging from the sea between the Cretaceous and Tertiary periods," and while the Maestricht Beds were being formed.

The general regularity of the surface of the Chalk beneath the Tertiaries is however departed from occasionally ; and in October, 1897, a fine section was for a short time exposed in a chalk-pit in Mr. Glasscock's brickyard here. The Chalk was channelled to a depth of 8 feet, as shown in the accompanying figure. Here, in my opinion, we have direct evidence of the local solution of the Chalk during the deposition of the Reading Beds, as shown by the subsidence of the lower beds into the hollows. There can

* *Recherches sur le terrain crétacé supérieur*, p. 182.



ERODED CHALK AND READING BEDS IN GLASSCOCK'S BRICK-YARD, HOCKERILL, OCTOBER 15TH, 1897.

ardly be any doubt, in our present state of knowledge, that the rotting away of buried banks of seaweed would furnish the solvent which eroded the Chalk on the scale shown in the figure.

NOTE II.

Woolwich and Reading Beds.—In the brickyards these rest upon an eroded surface of the Chalk, in which I have not been able to detect any tubes formed by the root-stocks of Algæ, and filled with glauconitic sand, as at Reading; nor have I been able to observe, or hear of, the occurrence of *Ostrea bellovacina* so common at Reading, Highclere,* and elsewhere at this horizon. Green-coated flints (occasionally pebbles) are common in the basement-bed, which is much more argillaceous than the overlying beds in the sections under notice. The upper stiff Plastic clay of the Katesgrove and Coley Hill pits on either side of the Kennet at Reading is wanting in the Rye Street section. [On either side of the Stort have I been able to detect any traces of leaf-bed, such as that observed by my former pupil, Mr. Mackesy, and myself in the sands of the Katesgrove Pit in the year 1880, and described later by Mr. J. S. Gardner (See *Brit. Assoc. Report*, 1885).]

The principal bed is a "brick-earth" in its composition, rough mottled by staining of iron oxide, as the stiff clay is in the leading pits. It is in all probability the equivalent of the mottled loam" and the "yellow sandy loam" of some of the well-sections of the district.

I have been unable to ascertain that any fossils have been found in the Reading Beds of this locality. The green coating of the flints (which are not generally rolled into pebbles) tells of the long action of decomposing vegetable matter (in this case probably sea-weeds) taking up iron in the form of soluble compounds, and thus enabling it to re-act upon the silica of the flint, to form silicate of iron; a similar reaction no doubt accounting for the rains of glauconite so common in the basement bed of this formation.† Silica occurs with such great variations in its molecular structure, that the action in such cases is, no doubt, selective, the iron in solution acting more readily upon the colloid (hydrated) varieties than upon the crystalline quartz.

If this view be correct, we can scarcely say that "the green coating of the flints is owing to the deposition of a salt of iron from the water" (See "*Mem. Geol. Surv.*," vol. iv, p. 59).

[At Mr. Glasscock's brickyard a bed of true glauconitic green-sand is met with, intercalated with the brick-earths. At the same

* See A. Irving, *Quart. Journ. Geol. Soc.*, vol. xlv, p. 164.

† Cf. A. Irving, "On Organic Matter as a Geological Agent," *Proc. Geol. Assoc.*, vol. xii, 227; also *Chem. and Phys. Studies in the Metamorphism of Rocks* (Longmans, 1889), pp. i. (d).

place further excavation into the flank of the hill has laid bare a section of the sands passing up into three to five feet of the stiff mottled clay (January, 1898). This gives the whole series a more complete "Reading" facies.]

NOTE III.

*On the "Herts Puddingstone."**—Sarsens are very commonly met with hereabouts, both with and without pebbles, the siliceous cementation being in all cases the same. Perhaps the most magnificent examples to be met with in the county are those in the grounds of Oak Hall, the residence of Mr. G. E. Pritchett, F.S.A., which the members who joined the excursion inspected. The largest block I should estimate to weigh from 6 to 8 tons; and there were others to be seen of huge dimensions. They were got from the bottom of the Boulder Clay, in a field near Whitehall, at an altitude of about 250 feet O.D., many years ago; and several pebbly and non-pebbly examples of fair size are to be seen still lying about the farm-premises there. Others of considerable size, full of pebbles, may be examined about the entrance of the timber-yard of Mr. J. L. Glasscock, close to the river Stort, but their history is unknown. Fragments of such conglomerates are found from time to time among the coarser rolled detritus near the bottom of the stratified gravels described above. These conglomeratic fragments are quite angular (at least on one side) and derived therefore from local sources. Such pebble-conglomerates are not, of course, confined to this locality. Two years ago I saw in the Ipswich Museum a large block of the same, obtained from the base of the plateau-gravels near the cemetery, resting upon Tertiary Sands, just as the non-pebbly Sarsens are found still in the Bagshot country, where for centuries they have been extracted for building and paving purposes.† (They are quite different lithologically from the conglomerates with angular discoloured flint fragments cemented by peroxide of iron, which form frequently an integral part of the plateau-gravels themselves, and are occasionally used for building purposes, as in the tower of the old church at Wokingham, and in the ancient Roman walls of Silchester.)

It seems a fair inference to draw from such facts as are stated here and in the Report of the Excursion, that these pebbly Sarsens of Herts, may be *agglutinated remains of Bagshot Pebble Beds*, which once extended over this portion of the Tamisian area, the unagglutinated portions of such pebble beds being represented, in

* One may still meet with the vulgar idea among the natives, that these are "breedin' stoans."

† It is probably well-known that the sagacious William of Wykeham perceived their value for durability, and scoured the country for many miles to procure them, for facing the older structure of Windsor Castle.

a disturbed state, by the gravels of Prestwich's Brentwood Series, to which reference has already been made.

[It is satisfactory to know that similar agglutinated masses of the Pebble Beds below the London Clay (such as one sees about Addington) are met with in the Croydon neighbourhood, as stated by Mr. Whitaker in the discussion of this paper on December 3rd.]*

ORDINARY MEETING.

FRIDAY, 5TH NOVEMBER, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

Frank Douglass was elected a Member of the Association.

The meeting then resolved into a *Conversazione*, and the following is a list of the exhibitors and their exhibits:—

THE DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY: Colour-printed *Index Maps* of the Geological Survey.

E. T. NEWTON: Arctic Fossils from Franz Josef Land.

W. WHITAKER: Cores from a Boring at Weeley, Essex (probably Silurian).

Dr. F. CORNER: A series of weapons, bones, pottery, etc., from Pile Dwellings in the Lea Valley (Crannog Sections).

W. F. GWINNELL: Miocene fishes; and photographs, chiefly in connection with excursions of the Association.

BENJAMIN HARRISON: A series of Eolithic Implements from the British Association Pits, 1894.

J. D. HARDY: A Micro-Camera, a simple means of photographing microscopic objects.

A. S. KENNARD: Mollusca from the Ightham Fissure.

F. R. B. WILLIAMS: Fossils from the London Clay, collected by the late Nathaniel T. Wetherell.

J. ALSTONE: Specimens of gold-bearing quartz, coal, and crocidolite, from the Transvaal, and of zinc and copper ores from Mount Usher Mine, Queensland.

B. MCNEILL: A fine series of enlargements of photographs taken during the excursions.

P. A. B. MARTIN: Palæolithic Implements.

UPFIELD GREEN: Upper Jurassic Cephalopoda from Russia, and fossils from Nassau.

ERNEST SWAIN: Arrow heads, etc., from the Mexican Border, Colorado.

J. T. HOTBLACK: Polished Flints from Plateau Gravel, Norwich; exhibited and explained by Horace B. Woodward.

G. C. CRICK: Model of the shell of *Ascoleeras*.

* See W. Whitaker, "Geology of London," *Mem. Geol. Survey*, p. 200.

- R. S. HERRIES : Asteroidea and Ophiuroidea from the Capricornus and Jamesoni Zones of the Lias, Boulby, Huntcliff, Staithes, and Robin Hood Bay, Yorkshire.
- J. R. TENNEAR : Photograph of Sarsen (?) Stone in drift above Upper Corallian Ironstone, Westbury, Wilts.
- J. SHEER : Quartz veins in Killas from North Cornwall.
- G. E. DIBLEY : Chalk Fossils and Mineral Structures in Chalk.
- A. S. FOORD : Models of the Witwatersrand Gold Fields, Transvaal.
- D. TAYLOR : A series of Flint Implements from Cissbury, Sussex.
- JOHN GRAY : Natural Petroleum from Oil Shales, Pentland, and from St. Catherine's Well, Liberton.
- J. FOX : Bone Musical Instruments.
- A. E. SALTER : Erratics from High Level Gravels in Dorset and Devon, with micro-sections.
- A. N. BUTT : Typical Rock specimens from the coal fields and gold fields of the Transvaal, and also from Helderfontein, Waterberg District, Transvaal, with sketch-maps and photos.
- A. MORLEY DAVIES : Upper Jurassic Fossils from Buckinghamshire and Oxfordshire.
- MISS C. A. RAISIN : Specimens and micro-sections of Serpentine and Amphibolite from the Vosges.
- H. FLECK : Igneous Rocks from North Wales, and micro-sections of same.
- W. J. ATKINSON and E. MONTAG : Basalt changing into White Trap, Bathgate Hills, Linlithgowshire, and other rocks from the Edinburgh district, with micro-sections.
- GEORGE POTTER : Ammonites from the Oxford Clay, St. Ives, Hunts.
- A. K. COOMARA-SWAMY : Six-sided column of basalt from Lennan Quarry, near Asbach, Siebengebirge.
- HENRY PRESTON : Photographs taken during the Edinburgh excursion.
- FREDERICK CHAPMAN : Ostracoda from the *Chara*-marl of Hitchin ; and *Coralliodendron* Limestone from Egypt.

ORDINARY MEETING.

FRIDAY, 3RD DECEMBER, 1897.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected Members of the Association :—

W. C. Daniel, Miss E. J. Cooke, Edward B. Wethered, J.P., F.G.S., F.C.S., S. Hazzledine Warren, F.G.S., G. H. Fowler, A. E. Cooper, G. J. Binns, F.G.S., F. Ross Thomson, Emil Montag, H. Vassall, M.A.

A paper was read by the Rev. Dr. A. IRVING on "The Geology of the Stort Valley, with special reference to the Plateau Gravels."

ANNUAL GENERAL MEETING.

FEBRUARY 4TH, 1898.

E. T. NEWTON, F.R.S., President, in the Chair.

Messrs. E. Montag and S. N. Glass, were appointed scrutineers of the ballot.

The following report of the Council for the year 1897 was then read :—

THE numerical strength of the Association on the 31st Dec., 1897, was as follows :—

Honorary members	16
Ordinary members—	
(a) Life members (compounded)	162
(b) Old country members (5s. annual subscription)	7
(c) Other members (10s. annual subscription)	354
	<hr/>
Total	539
	<hr/>

During the year thirty-eight new members were elected. The Council regrets that the Association has lost seven members by death : Sir J. R. G. Maitland, A. M. Dunlop, Jos. William Crossley, Samuel Harraden, Arthur G. Ogilvie, William V. Murray, and John Reid. Sir James Ramsay Gibson Maitland, Bart., F.L.S., F.G.S., F.Z.S., who died on November 9th last, aged forty-nine, was better known in connection with fish-culture than as a geologist. His celebrated trout farm at Howietown, near Stirling, visited by the Association last summer, is probably the largest and most complete establishment of its kind in the world. He was elected a member of the Association last February, and had he not been detained in Edinburgh, would have acted as Director of the excursion to Stirling on July 28th last. He was well known to many members of the Association, and was extremely popular. William V. Murray was elected a member of the Association in 1872. He was for many years a frequent attendant at the meetings and excursions, and his kindly face and genial manner will long be remembered by all with whom he was accustomed to come in contact.

The income of the Association for 1897 was £251 17s. 8d., besides £5 os. 6d received on account of sales of the *Record of Excursions* and *Paris Basin*; and the expenditure was £240 4s. 1d. Thus, while the income remains about the same as last year, there is a substantial reduction in the expenditure, notwithstanding the increased sum which it has been found necessary to spend on the library. In view of still further sums being

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required for the same object, for binding serials and printing the catalogue, your Council has thought it advisable to keep the whole of the balance, £42 15s. 11d., in hand, and this amount is, therefore, carried forward to next year's account.

During the year five numbers of the PROCEEDINGS, consisting of 210 pages of text, with eight plates and twenty other illustrations, have been published. Your thanks are due to the authors for their contributions, to Messrs. Burrows and Holland for presenting part of the illustrations for their paper, and to Mr. Sherborn for the drawings for Plate III.

In last year's Report mention was made (p. 58) of the proposed removal of the Library to St. Martin's Public Library. The arrangements then contemplated have been carried into effect, and the bound books transferred to that institution (115, St. Martin's Lane, Charing Cross). Books deposited there may be borrowed by Members of the Association at any time when the Library is open to the public.

The bequest by Sir Joseph Prestwich of a nearly complete set of the publications of the Palæontographical Society has permitted the breaking up of the annual volumes originally belonging to the Association, and all the completed Memoirs have been bound and deposited at St. Martin's. The annual volumes bequeathed by Sir J. Prestwich are retained at University College, where they are accessible, for reference only, on the evenings of meetings.

The Memoirs of the Société Paléontologique Suisse have also been bound in subjects, and the Proceedings of various other societies have been bound and rendered accessible. There are still a number of volumes to be bound. As soon as this can be accomplished the printing of the new catalogue will be proceeded with.

The following is a list of the Papers read at the evening meetings :

"On the Geology and Physical History of the Alps," by Professor T. G. BONNEY, F.R.S.

"The Evidence for the Presence of Man in the Tertiary Period," being the address of the President, E. T. NEWTON, F.R.S.

"The Physical History of Romney Marsh," by GEORGE DOWKER, F.G.S.

"The Origin of the High-Level Gravel with Triassic Débris adjoining the Valley of the Upper Thames," by H. J. OSBORNE WHITE, F.G.S.

"An Outline of the Geological History of the Rocks around Edinburgh," by J. G. GOODCHILD, H.M. Geol. Survey.

"The Excursions from Bathgate to Linlithgow, and from St. Monans to Elie," by Prof. JAMES GEIKIE, LL.D., F.R.S.

"Fish Remains in the Abden Bone-bed," by R. H. TRAQUAIR, M.D., F.R.S.

"The Stirling District," by H. W. MONCKTON, F.L.S., F.G.S.

"The Geology of the Stort Valley, with Special Reference to the Plateau Gravels," by the Rev. Dr. A. IRVING, F.G.S.

Lectures were delivered by Prof. H. A. MIERS, M.A., F.R.S., on "Some Properties of Precious Stones"; and by W. W.

WATTS, M.A., F.G.S., on "Coral Islands." Your thanks are due to all these gentlemen.

A very successful *Conversazione* was held in November. A full list of the exhibits has been published in the PROCEEDINGS, and your thanks are due to those members who contributed to the success of that evening.

The following museums and collections were visited in 1897:—

March 20th.—The Geological Galleries, Numbers vii and viii, of the British Museum (Natural History), Cromwell Road. Director: Dr. HENRY WOODWARD, F.R.S., F.G.S., Keeper of the Department of Geology, assisted by Messrs. G. C. CRICK, F.G.S., G. F. HARRIS, F.G.S., H. W. BURROWS, A.R.I.B.A., and R. BULLEN NEWTON, F.G.S.

March 27th.—The Royal College of Surgeons, Lincoln's Inn Fields. Director: Prof. CHARLES STEWART, F.R.S., M.R.C.S.

June 6th.—The collections of S. S. Buckman, Esq., F.G.S., at Elborough, Charlton King's, near Cheltenham. Director: S. S. BUCKMAN, F.G.S.

July 10th.—The collections of A. N. Leeds, Esq., F.G.S., at Eyebury, near Peterborough. Director: A. N. LEEDS, F.G.S.

August 2nd.—The Museum of Science and Art, Edinburgh. Director: J. G. GOODCHILD, F.G.S.

The following is the list of excursions made during the past year. Detailed reports will be found in parts 3 and 5 of the PROCEEDINGS, vol. xv:

DATE.	PLACE.	DIRECTORS.
April 3rd	Chesham (Bucks)	Upfield Green, F.G.S.
April 10th	Aylesbury (Bucks)	A. Morley Davies, F.G.S., and Percy Emary, F.G.S.
April 15th to 20th (Easter)	Dover, Folkestone, and Romney Marsh (Kent)	G. Dowker, F.G.S., W. F. Gwinnell, F.G.S., Dr. A. W. Rowe, F.G.S., and C. D. Sherborn, F.G.S.
May 1st	Cookham (Berks.)	Ll. Treacher, F.G.S.
May 8th (Whole Day)	Southboro' and Tunbridge Wells (Kent)	G. Abbott, M.R.C.S.
May 15th	Chiselhurst (Kent)	W. Whitaker, F.R.S., and T. V. Holmes, F.G.S.
May 22nd	Erith (Kent)	Flaxman C. J. Spurrell, F.G.S.
June 5th to 8th (Whitsuntide)	Cheltenham (Gloucestershire)	E. Wethered, F.G.S., and S. S. Buckman, F.G.S. —
June 19th (Whole Day)	Leighton (Bedfordshire)	A. C. G. Cameron.
June 26th	Red Hill and Merstham (Surrey)	G. J. Hinde, Ph.D., F.R.S., and W. Whitaker, B.A. F.R.S.
July 3rd	Woking (Surrey)	F. Meeson.
July 10th (Whole Day)	Peterborough (Northamptonshire)	A. N. Leeds, F.G.S., and A. S. Woodward, F.G.S.
July 17th	Bishop's Stortford (Herts.)	Rev. Dr. A. Irving, F.G.S.

DATE.	PLACE.	DIRECTORS.
July 26th to 31st (Long Excursion)	Edinburgh	Prof. James Geikie; LL.D., D.C.L., F.R.S., J. G. Goodchild, F.G.S., and H. W. Monckton, F.G.S.
September 4th (Whole Day)	Whitchurch, Oving, and Quainton (Bucks.)	A. M. Davies, B.Sc., F.G.S.
September 18th	Otford (Kent)	A. S. Kennard.

The interest of members in the excursions of the Association during the past year has been fully maintained.

Your thanks are due to the Directors of the excursions, also to the following ladies and gentlemen for assistance and hospitality :

General Cockburn and Captain McDakin, at Dover ; Mr. Turner of the Folkestone Waterworks ; Mr. Elliott, at Cookham ; the Directors and Manager of the Southborough Waterworks Company ; Mr. and Mrs. E. A. Webb, at Chiselhurst ; the Mayor of Cheltenham ; Captain Willis, Mr. C. Upton, Mr. W. J. Dale, and Mr. and Mrs. Buckman, at Cheltenham ; Mr. and Mrs. Meeson, at Woking ; Mr. E. Wheeler, of the G. N. Ry., at Peterborough ; Mr. Laurie Frere, Mr. Pritchett, and Mr. Glasscock, at Bishop's Stortford ; Mr. Conacher of the North British Railway at Edinburgh ; Sir James Maitland, Bart., and Miss Maitland at Sauchieburn, Stirling ; Mr. Thompson, Manager, Howietown Fishery Co., and the Royal Scottish Geographical Society.

Your thanks are also due to Sir Archibald Geikie, D.Sc., D.C.L., LL.D., F.R.S., Director-General of the Geological Survey for the presentation of Sheets (1 Drift, 4 Solid, 6, 7, and 9 Drift) of the Geological Map of England, and of Sheets 2, 4, 6, 7, 9, 10, 11, 13, and 15 of the Index to the Geological Map of England and Wales, and of Sheets 31, 32, 40, 41 of the Geological Map of Scotland.

Your thanks are also due to Mrs. Topley and to Mrs. A. H. Green for the presentation of Sheets 18, 23, 24, 25, 54 N.W., 60 S.E., 61 S.W., 63 S.W., 71 N.W., 72 S.E., 72 S.W., 87 N.E., and 87 S.E. of the Geological Survey of England.

The management and arrangement of the excursions of the Association during the past year have been in the hands of the following committee : H. W. Monckton (chairman), H. A. Allen, Miss M. C. Foley, R. S. Herries, T. Leighton, E. P. Ridley, W. P. D. Stebbing, and A. C. Young. Your thanks are due to the members of this committee for the able manner in which they have carried out the work of organising the excursions.

The following committee has been appointed for the management of the excursions during the ensuing session : H. W. Monckton (chairman), Miss M. C. Foley, F. Meeson, E. P. Ridley, A. E. Salter, W. P. D. Stebbing, and A. C. Young ;

and it is recommended that the appointment of this committee be confirmed as soon as the new Council meets.

Your thanks are due to the Council of University College for the facilities they continue to offer the Association in the use of rooms, and to Mr. Horsburgh, the secretary of the college, for his courtesy and ready assistance.

There are many changes in your House List. Mr. Newton now retires from your Presidency. During his term of office he has displayed an untiring devotion to the interests and welfare of the Association. The regularity of his attendance at both the meetings and the excursions, and also the tact and energy with which he has presided over your affairs, have contributed in no small degree to the success of the Association during the past two years. You are also indebted to him for his valuable and impartial summary of the evidences which have from time to time been brought forward in favour of the existence of man in the Tertiary period.

During the year Mr. Sherborn has retired from the office of Secretary. Your thanks are especially due to him for the able and conscientious manner in which he has discharged the arduous duties of that office during the past eight years.

Mr. Leighton retires from the Vice-Presidency and from the Council. Mr. Watts, Mr. Davies, Mr. Rudler, and Prof. Meldola retire from the Council. Your thanks are due to these gentlemen for their assistance in conducting the business of the Association.

The names of those suggested by your Council to fill the vacant offices will be found on the ballot paper.

On the motion of Mr. T. V. Holmes, seconded by the Rev. Prof. J. F. Blake, the Report was adopted as the Annual Report of the Association.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year :

PRESIDENT :

J. J. H. Teall, M.A., F.R.S., V.P.G.S.

VICE-PRESIDENTS :

Prof. T. G. Bonney, M.A., D.Sc., LL.D., F.R.S.	
Lieut.-General C. A. McMahon, V.P.G.S.	| E. T. Newton, F.R.S., F.G.S., F. — .Z.S. George Potter, F.R.M.S.

TREASURER :

R. S. Herries, M.A., F.G.S.

SECRETARIES :

Percy Emary, F.G.S.

| Horace W. Monckton, F.L.S., F.G.S.

EDITOR :

H. A. Allen, F.G.S.

LIBRARIAN :

Wheatley J. Atkinson, F.G.S.

TWELVE OTHER MEMBERS OF COUNCIL :

H. W. Burrows, A.R.I.B.A.	T. V. Holmes, F.G.S.
George C. Crick, A.R.S.M., F.G.S.	John Hopkinson, F.L.S., F.G.S.
Miss M. Crosfield	Dr. Edward Johnson
Henry Fleck, F.G.S.	A. E. Salter, B.Sc., F.G.S.
Miss Mary C. Foley, B.Sc.	C. Davies Sherborn, F.Z.S., F.G.S.
J. D. Hardy	W. Whitaker, B.A., F.R.S.

On the motion of Captain Stiffe, seconded by Professor T. G. Bonney, the thanks of the Association were unanimously voted to the officers and members of Council retiring from office, to the auditors, and to the scrutineers.

The President then delivered the annual address, entitled, "Palæolithic Man."

On the motion of Mr. L. Belinfante, seconded by Lieut.-General McMahon, it was unanimously resolved that the President's address be printed in full.

This terminated the Annual Meeting.

ORDINARY MEETING.

FRIDAY, 7TH JANUARY, 1898.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected Members of the Association :—
Abraham Farrar, junr., F.G.S., Miss Letitia Hales, A. Das.

Dr. E. JOHNSON and Mr. A. S. KENNARD were elected auditors.

Mr. L. L. BELINFANTE, M.Sc., then gave an interesting account of the excursions in Russia made in connection with the International Geological Congress, 1897, dealing more especially with the excursion to the Urals, and illustrated his remarks by lantern slides from photographs taken by Mr. Emary during that excursion.

ORDINARY MEETING.

FRIDAY, 4TH FEBRUARY, 1898.

J. J. H. TEALL, M.A., F.R.S., President in the Chair.

H. A. Hinton, A.R.C.S., A.R.S.M., F.G.S., was elected a Member of the Association.

There being no further business, the meeting then terminated.

PALÆOLITHIC MAN.

By F. T. NEWTON, F.R.S., F.G.S., F.Z.S.

(Being the Presidential Address delivered February 4th, 1898.)

WHEN last year I had the honour of addressing the GEOLOGISTS' ASSOCIATION from the presidential chair I endeavoured to lay before you, in an impartial manner, the evidence which had been brought forward in favour of Man's existence on this planet in Tertiary times, and, although some of the evidence was very cogent, in no case did it seem to me conclusive. On the other hand, as was then pointed out, the presence of Man in Quaternary times has long since been proved; that is to say, his co-existence with the Mammoth and other extinct animals in caves and river deposits of Pleistocene age, is now positively known by the presence in these beds of flint implements, which are universally accepted as the result of human handiwork.

But now other questions arise—What kind of man was it that made these implements? Have any parts of his skeleton been found which might give us some idea of his physical characters? And, if such remains have been discovered, may we infer from them that Palæolithic Man resembled his descendants of the present day, or that he was of a lower type or less intelligent?

Human bones and skeletons, more or less imperfect, and supposed to be of Pleistocene age, have often been recorded; but a close investigation has, in nearly all such cases, proved them to be of much more recent origin, or has shown that there were very grave doubts as to their authenticity.

It would be tedious and unprofitable to attempt even a brief notice of the many discoveries which have been made known, but so much has been done already to eliminate the more doubtful cases* that it will only be necessary for us to consider some of the more interesting records, and especially those which have been made within the last few years.

Canstadt Skull (1700).—In the year 1700, Duke Ludwig of Würtemberg, when excavating a supposed Roman oppidum at Canstadt, found a great number of bones of Cave-bear, Elephant, and Hyæna, and these were described by Spleiss in 1701, but no mention was made of human remains. It was not until 135 years afterwards that Jæger† figured a portion of a human skull, which, at this later date, was thought to form part of the collection made in the year 1700. As there was no mention of this specimen in the earlier account, there must always be the greatest uncertainty as to the origin of the "Canstadt" skull—

* See, among others, Prof. W. Boyd Dawkins, "Cave Hunting," and MM. Fraipont and Lohest, *Archiv. de Biol.*, vol. vii, 1887, p. 586.

† "Fossilien Saugeth," Würtemberg, 1835.

This cranium is said to resemble that from the Neanderthal in having large supra-orbital ridges and narrow frontals, as well as very thick bones.

A renewed interest has been awakened in this skull by the discoveries of MM. Fraipont and Lohest* at Spy, where human skulls, which are held to be of the same type, were found in such relation to the bones of Elephants, etc., as to leave little doubt of their being of Palæolithic age.

Gailenreuth (1774).—The famous cave of Gailenreuth, near Muggendorf, in Franconia, which has yielded such a number of remains of Cave-bear, Mammoth, Hyæna, and other extinct animals, was first explored by Esper, in the year 1774, and subsequently by several other workers, including Dr. Buckland,† who brought over specimens to this country, which are now in the Oxford Museum. Prof. Boyd Dawkins‡ has found among these relics a human skull and some black coarse pottery, which, although found apparently in close relation with the extinct mammals, does not belong to the same period. Prof. Dawkins says this skull is remarkable for the great width of the parietal protuberances and the flattening of the upper and posterior region of the parietal bones; it has a cephalic index of $\cdot 81$, and is therefore of the broad type (brachycephalic)

The form of this skull, as well as the coarse pottery found in the same deposit, indicate a date not earlier than Neolithic, and possibly much later.

Lahr (1823).—In the year 1823 M. Ami Boue§ found scattered human bones at a depth of 5 ft. in a river deposit near the village of Lahr at a height of 160 metres above the River Schutter, which falls into the Rhine, at Strasbourg.

These bones, it seems, were sent to Cuvier for description, but appear to have been lost, as no account of them was ever published, and they have not since been seen.

Paviland Cave (1823).—The Goat's Hole, at Paviland, in Glamorganshire, was explored by Buckland|| in 1823. It is situated in a cliff on the coast, and is nearly 40 ft. above the shore. The red loam of the floor contained bones of Elephant, Rhinoceros, Hyæna, and Bear; and with these was found a large human skeleton, together with pieces of charcoal, a small chipped flint, sea-shells, and ivory ornaments. The soil, Dr. Buckland says, "appears to have been disturbed by ancient digging"; and Prof. Dawkins¶ is doubtless correct in relegating this discovery to the category of Neolithic interments.

Engis Skull (1833).—The celebrated human skull from the

* *Archiv de Biol.*, 887.

† "Reliquiæ Diluvianæ," p. 133.

‡ "Cave Hunting," p. 240.

§ *Ann. Sci. Nat.*, 1829, Bibl., vol. xviii, and *Bull. Soc. Géol. France*, vol. i, p. 105, 1830-31.

|| "Reliq. Diluv.," p. 82.

¶ "Cave Hunting," p. 232.

Engis cave near Liege was discovered by Dr. Schmerling * in the year 1833, in a mass of breccia, with bones of extinct mammals. Mr. E. Dupont† has more recently found other human bones, worked flints, and a fragment of coarse earthenware in the same place. The skull is said to be dolichocephalic with an index of 70, but presents no marked peculiarities or signs of degradation, and judging from the outline given by Busk,‡ it quite justifies Huxley's§ remark that, "It is in fact a fair average human skull, which might have belonged to a philosopher, or might have contained the thoughtless brains of a savage."

The form of this skull and the pottery found in the same stratum, point to its being of later date than the mammalian bones with which it was associated; and although its exact age is uncertain, there seems no likelihood of its being earlier than Neolithic.

Stægenæs (1843).—In the year 1844 Sven Nilsson|| published an account of two human skeletons which had been found the previous year at Stægenæs, in the district of Bro, Sweden. These skeletons were discovered at a depth of three feet from the surface in a bed of shells, situated 100 feet above the river. The shells are said to be in horizontal layers and quite undisturbed. The skull, as figured, does not present any remarkable characteristics, and although thought by MM. Quatrefages and Hamy¶ to be of the Neanderthal race, is considered by M. G. de Mortillet** to be of much more recent date than the Mammoth.

Denise (1844).—Sir Charles Lyell†† has given a long account of the discovery of certain human remains in a volcanic tuff at Denise, near Puy en Velay, France, which had been described by M. Aymard in 1844,‡‡ and were afterwards noticed by Dr. Sauvage,§§ and M. Fraipont|||. These remains include portions of two skulls, which are said to have large supraciliary ridges and receding foreheads, but the published figure of one of them does not show these characters in any marked degree.

At first these skeletons were supposed to be associated with *Elephas meridionalis*, Nesti; subsequent investigation showed that such was not the case, but that the human bones were probably included in and coeval with, the latest eruption of the Le Puy volcanoes; and as the lava streams extended almost to the bottoms of the valleys, were certainly of later date than the

* "Recher. Oss. Foss. Cavernes," Liege, 4to, 1833-34.

† "L'homme pendant les Ages de la Pierre," etc., edit. I, p. ix, 1871.

‡ *Nat. Hist. Rev.*, 1861, vol. i, pl. v.

§ "Man's Place in Nature," 1863, p. 156; and Lyell's "Antiquity of Man," p. 63.

|| *Congres Nat. Scand.* Stockholm, 1844. See also "Primitive Inhabitants of Scandinavia," translation by Sir J. Lubbock, 1868.

¶ "Crania Ethnica."

** "Le Préhistorique Antiquité de l'homme," 1883, p. 353

†† "Antiquity of Man," 1863, p. 194.

‡‡ *Bull. Soc. Géol. France*, ser. 2, vol. ii, 1844-5.

§§ *Revue d'Anthrop.*, vol. i, p. 289, 1872.

||| *Archiv. de Biol.*, vol. vii, p. 590, 1887.

valleys themselves. The alluvium of these valleys is said to contain bones of Mammoth and Woolly Rhinoceros, and it has been supposed that the human remains were of the same age as these mammals, but there appears to be no certainty that such is the case; the lava flow may have taken place since the deposition of the alluvium, and the age of the remains is, therefore, uncertain.

Aurignac Cave (1852).—This cave, which is near the Pyrenees, in the department of the Haute Garonne, was described by M. Lartet* in 1862. It is situated in the face of a steep escarpment, forty-five feet above the brook called Rodes. It is said that in the year 1852 a labouring man thrusting his hand into a rabbit-hole, drew out a human bone; this excited his curiosity, and, by subsequent digging, he disclosed a slab of rock covering the entrance to a large cavity, in which remains of not less than seventeen human skeletons were found. These remains were piously buried in the cemetery.

It was not until the year 1860 that M. Lartet accidentally heard of the existence of bones of Cave-bear, Rhinoceros, and other extinct forms which had been found at the same time as the human remains; but the resting-place of the latter, in the cemetery, could not be traced.

M. Lartet at once investigated the circumstances of this discovery, and came to the conclusion that the human skeletons were of the same age as the extinct mammals. This view was also held by Sir Chas. Lyell;† but later researches have shown that the fossil bones of the extinct mammals occurred in a stratum of earth below the deposit where the human remains were found, and, besides this, a fragment of pottery found with the latter‡ make it almost certain that the Aurignac Cave was a Neolithic place of burial.

The only human bones now known from this cave are the pieces of human jaws figured by Quatrefages and Hamy,§ and these fragments give no characters of importance.

Bruniquel (1863).—The Cave of Bruniquel, Tarn et Garonne, was explored by the Vicomte de Lastic in 1863-4 and described by Prof. Owen;|| it is situated in a cliff about 40 feet above the river Aveyron. The floor of the cave was covered by a sheet of stalagmite, below which was a bed 4 or 5 feet thick with much charcoal and largely cemented into a breccia. In this bed were many bones of animals such as Rhinoceros, Reindeer, etc., as well as Palæolithic implements of flint and bone; on some of the latter were outlines of animals.

With these mammalian remains, human bones were found,

* *Ann. Sci. Nat. Zool.*, ser. 4, vol. xv, p. 177.

† "Antiquity of Man," 1863, p. 181.

‡ See "Cave Hunting," p. 242.

§ "Crania Ethnica," pl. 2, figs. ix, x, xi.

|| *Phil. Trans.*, vol. clx, p. 517.

evidently belonging to several individuals ; but the only calvaria which could be measured was of the long type (dolichocephalic). One at least of the skeletons had been buried in a crouching position. Prof. Owen thought these human skeletons were of the same age as the mammals, that is Palæolithic ; but Prof. Boyd Dawkins * is much more likely to be correct in referring them to the Neolithic period.

Neanderthal Skull (1857).—This, the most famous of fossil skulls, was found, with other parts of the skeleton, in the year 1857, in a limestone cave in the Neanderthal, near Hochdal, between Düsseldorf and Elberfeld. A description of the skull was given by Prof. D. Schaaffhausen,† and translated with further remarks by Prof. G. Busk.

The cave is about 60 feet above the bottom of the valley ; it is about 15 feet deep, 7 or 8 feet wide, and high enough to admit a man. The floor, which is uneven, was covered with 4 or 5 feet of mud in which the skeleton was said to have been found, lying with the head towards the entrance. Only a few of the bones were preserved, as its human origin was not at first suspected.

The appearance of the skull is well known, and has been often described, its chief characteristics being the large size of the supra-orbital ridges, the receding forehead, the low crown, and the long-oval form, the cephalic index being '72 or '73.

The age of this skull has always been very uncertain, nothing being found with it which might give a clue. A few years later a similar cave near by, at Feldhofen, yielded remains of Elephant and other extinct forms ; but this has not removed the doubt as to the age of the mud in the original cave, neither has it disproved the possibility of the human bones being the result of a more modern interment. In the light of the discoveries at Spy, in Belgium, to be presently alluded to, the Neanderthal skull has again become of great interest.

Grotto d'Arcy-sur-Cure, Yonne (1860).—A portion of a human jaw was found in this cave by M. de Vibraye‡ together with remains of Cave-bear, Woolly Rhinoceros, Mammoth, and other mammals. Judging from the account of the discovery of the specimen there seems no reason for doubting its Palæolithic age. The jaw itself presents no peculiarities which could be taken as positive evidence for its antiquity ; but still the illustrations of it seem to show a somewhat receding chin, and this is held to be a low type. M. Fraipont§ accepts the jaw as a relic of Palæolithic Man.

Moulin Quignon Jaw (1863).—This celebrated human jaw was said to have been found by a workman when digging at Moulin Quignon, near Abbeville, and was shown to M. Boucher

* "Cave Hunting," p. 248.

† *Müller's Archiv.*, 1858, p. 453. See Translation by Busk. *Nat. Hist. Rev.*, 1861, p. 155.

‡ *Bull. Soc. Geol. France*, ser. 2, vol. xvii, p. 471, 1860.

§ *Archiv. de Biol.*, vol. vii, p. 597.

le Perthes in 1863;* it was supposed to have come from a depth of $4\frac{1}{2}$ metres in Palæolithic gravel, at a spot about 30 metres from the river Somme. At the time, this jaw gave rise to a very warm controversy; some thinking it truly Palæolithic, while others refused to accept it as such. Sir C. Lyell, who at first† believed in the genuineness of this discovery, afterwards said,‡ "we must, I think, give up all claims to authenticity for the celebrated jaw from Moulin Quignon."

M. de Mortillet§ shows good reason for thinking that it, like many of the forged flint implements said to be from the same place, was not obtained as stated, but was brought there by the workman in order to obtain money. And M. Fraipont|| throws it on one side as doubtful.

Larzac (1864).—A human cranium and some other remains were discovered by M. de Sambycy in a cave at Larzac in Aveyron; the skull was described by Pruner Bey¶ as possessing strongly developed glabella and brow-ridges, in which particulars it resembled the Neanderthal cranium. Although the age of the remains is very doubtful, MM. Quatrefages and Hamy** regard this cranium as belonging to the Neanderthal race.

Eguisheim (1865).—M. Faudel†† found in a river deposit at Eguisheim near Colmar (Lower Rhine) the fragments of a human cranium with an Elephant's tooth and other remains. The cranium is extremely dolichocephalic, and much resembles that from Canstadt; the brows are large, but less so than in the Neanderthal alvaria. Prof. Dawkins‡‡ and many other Anthropologists, accept this cranium as a representative of the Palæolithic or Neanderthal race.

Naulette jaw (1865).—This human jaw, which has caused so much discussion of late years, was found by M. E. Dupont§§ in the Trou de la Naulette at Furfooz, near Dinant, and was accompanied by bones of Mammoth, Rhinoceros, Reindeer, etc. The entrance to the Naulette cave is narrow, and situate about 8 feet above the River Lesse, but the interior forms a large chamber, the floor of which is covered to a depth of 11 metres by clay soil, which is separated into layers by seven deposits of stalagmite. It was under five of these stalagmitic floors that the human jaw was found, together with a few other bones of the skeleton.

The Naulette jaw is small, and consequently has been thought to have belonged to a female; it is, however, remarkably robust,

* See "Antiquités Celtiques," vol. iii.

† "Antiquity of Man," edit. 3, p. 515

‡ *Ibid*, edit. 4, p. 190.

§ "Le Préhistorique Antiquité de l'Homme," p. 242.

|| *Archiv. de Biol.*, vol. vii, p. 595.

¶ *Bull. Anthropol. Paris*, vol. vi, p. 29, 1865.

** "Crania Ethnica."

†† *Bull. Soc. Hist. Nat. de Colmar*, 1867.

‡‡ "Early Man in Britain," p. 167.

§§ *Bull. Acad. Roy. Belge*, ser. 2, vol. xxii, 1866.

and the horizontal ramus is deep when seen in profile, the chin recedes instead of projecting as it does in normal jaws of the present day ; in both these particulars it holds a position intermediate between the jaws of modern Man and those of Apes. The molar teeth are absent, but their sockets seem to show that the hindmost or wisdom tooth was larger than those in front of it, and this again is a characteristic of ancient human dentition and seldom occurs in modern Man. Certain muscle marks on the inner side of the chin are said to be unlike what are found in modern human jaws, and to resemble more the peculiarities seen in Apes.

The conditions under which this jaw was found seem to exclude all grounds for doubting its Palæolithic age, and its form agrees with others which are now acknowledged to be of like antiquity.

Cro-Magnon (1868).—The Cro-Magnon cave is near Les Eyzies, on the banks of the Vezère, in Perigord ; it was disclosed in 1868, when the railway embankment was being made, and was described by MM. Lartet and Christy ; * it is situated at the base of a low cliff, and is formed by a projecting ledge of Cretaceous limestone. The floor of this cave is covered, to a great thickness, with *débris* fallen from the roof, and then by several irregular layers containing charcoal, bones and worked flints. Towards the upper part of these deposits is one especially thick bed with ashes, which contained great numbers of worked flints and bones, above this is a yellowish clay, also with bones and flints, in the upper part of which several human skeletons were found. The mouth of the cave and the overlying shelf of rock were covered by 4 metres of *débris* fallen from the cliffs above, this large accumulation of material bearing testimony to the great antiquity of the occupants of the cave.

On the surface of the yellow clay, in a small unfilled cavity at the back of the cave, the skull of an old man was found around this, but covered by the clay, were parts of four individuals, one being a woman whose skull has a deep wound in front, partly healed, showing that she must have lived some weeks after receiving the wound.

These skeletons were thought by Lartet to be of Palæolithic age. That the cave was occupied for a long period by generations of Palæolithic hunters is freely admitted, but it is by no means clear that the skeletons belonged to the same age ; indeed, it is highly probable, as pointed out by Prof. Boyd Dawkins,† that these skeletons are the result of a Neolithic interment.

The old man of Cro-Magnon had a straight face, a good forehead, was about 5 ft. 11 in. in height, and had flattened (platycnemic) tibiæ, thus presenting the physical characters of a Neolithic skeleton.

* "Reliquiæ Aquitanicæ."

† "Cave Hunting," p. 225.

Clichy, Paris (1868).—M. E. Bertrand* discovered the greater part of a human skeleton, with Elephant and other remains, in a gravel-pit at Clichy, Paris. M. de Mortillet† questions the Quaternary age of the human remains; their dark red colour not corresponding with the gravel in which they were supposed to have been found, but with the overlying stratum, which is of much more recent date. MM. Quatrefages and Hamy‡ took upon the skeleton as that of a female of the Neanderthal race.

Brux, Bohemia (1872).—A human skull and other bones were described by M. E. T. Hamy§ in 1872 from Quaternary river deposits at Brux, in which they were found at a depth of 3 feet (5 feet from surface of ground). The brow ridges are very pronounced, and the forehead is low; the skull has, judging from the figures, a striking resemblance to the Neanderthal alvaria; and MM. Quatrefages and Hamy,|| as well as M. G. le Mortillet,¶ refer these remains to the Neanderthal race. Other authorities, however, think they may be of much more recent origin.

Trou du Frontal (1871).—Sixteen human skeletons were found in this rock shelter on the river Lesse by M. Dupont,** and were thought by him to be of Palæolithic age. The skeletons were found at the back part of the rock cavity, and were closed in by a slab of stone, which was covered by the *débris* of rock which had accumulated outside. Beneath this *débris* and outside the shelter, broken bones of animals were found, including Lemming, Beaver, Goat, etc.; but apparently no extinct forms. With the skeletons were found flint-flakes, various ornaments, and a curious round-bottomed urn. The two skulls which could be measured proved to be brachycephalic; but fragments of another are said to indicate a long skull. Prof. Boyd Dawkins†† thinks these skulls belong to the same races as the round and long skulls which have been found in other Neolithic caves and tombs in France.

Mentone Cave (1872).—M. Rivière‡‡ when exploring the cave at Cavillon, near Mentone (sometimes called Baoussé-Roussés) discovered several human skeletons in association with bones of Mammoth, Rhinoceros, Lion, Hyæna, etc., at a depth of six and a half metres. The human remains had the bones so nearly in their natural relations that one of the skeletons, lying upon its side in a mass of cave-earth, was taken to Paris, and is now

* *Bull. Soc. Anthropol. Paris*, ser. 2, vol. iii. 1883.

† "Le Préhistorique," p. 346.

‡ "Crania Ethnica."

§ *Revue d'Anthrop.*, vol. i, p. 669, 1872.

|| "Crania Ethnica."

¶ "Le Préhistorique," p. 238.

** "L'Homme pendant les âges de la Pierre," p. 56.

†† "Cave Hunting," p. 238.

‡‡ *Intern. Con. Prehist. Arch.* Brussels.

preserved in the Jardin des Plantes. A photograph of it was reproduced by M. Rivière in his paper.

The skeletons were thought to be of the same age as the Mammoth with which they were associated, but Prof. Boyd Dawkins* has shown reasons for believing them to be much more recent; and M. de Mortillet† is of opinion that, although the Mentone cave-earth is of the age of the Mammoth, yet the human skeletons, which had been very carefully buried, were of a later date, for the presence with them of implements of bone, of a pierced-shell head ornament, and of a polished stone implement pointed to their being of Robenhausian age (Neolithic). M. Rivière says the skull is long, the femora carinate, and the tibiæ platycnemic.

In 1892 M. Rivière‡ published a note on three new skeletons from the Mentone Caves, which were said to be of great size, and to resemble in the greater part of their characters the Cro-Magnon race. The heights of the skeletons are given as 1·85 metres (= 6 ft. 0 $\frac{3}{4}$ in.), 1·9 metres (= 6 ft. 2 $\frac{7}{8}$ in.), and 2 metres (= 6 ft. 6 $\frac{3}{4}$ in.).

These later discoveries are accepted by some writers as of Palæolithic date, but it is more generally thought that, like the Cro-Magnon man which they so much resemble, they are of Neolithic age.

Lombrive Cave.—MM. Garrigou, Filhol, and Rames§ discovered in this cave, which is in the department of Ariège, two human skulls, together with bones of animals, only one of which, the Reindeer, seemed to point to any great antiquity; and this, as Prof. Dawkins says, may have lingered in the neighbourhood of the Pyrennees, as it did in Scotland, to a comparatively modern date. The skulls, are broad, and may very well be of Neolithic age, while the presence with them of *Bos longirifrons* shows that they cannot be of earlier date.

Colombi Cave (1873).—Prof. Capellini|| has described this cave, which is situated in a cliff overlooking the sea in the Island of Palmaria, Gulf of Spezzia. In the red earth covering the floor of the cave were found flakes and scrapers with pottery and a bone needle, besides bones of Ox, Goat, Pig, etc., and with them bones of children and young people which had been cut and, in one case, burnt. These were supposed to be evidence of Palæolithic cannibalism. Prof. Dawkins¶ accepts this as proof of cannibalism, but thinks the implements and bones found with them indicate a Neolithic or possibly later date.

Schipka in Moravia (1881).—Another human jaw was found

* "Cave Hunting," p. 257.

† "Le Préhistorique," etc., p. 390.

‡ *Comptes Rendus*, vol. cxiv, p. 567, and *La Nature*, 1892, p. 305.

§ See Vogt, "Lectures on Man," p. 329, and Dawkins "Cave Hunting," p. 257.

|| *Prehist. Cong. Bologna*, vol. for 1871, p. 391, 1873.

¶ "Cave Hunting," p. 259.

by M. Maschke in a cave at this locality in association with Mammoth and other extinct forms and is accepted by M. Fraipont* as of the Neanderthal race.

Tilbury Man (1883).—Parts of a human skeleton were found in the gravel at Tilbury Docks at a depth of 34 feet, and were submitted to Sir Richard Owen,† who described them as the remains of a Palæolithic Man; his reason for assigning so great an antiquity to them being, apparently, the form of the skull and the great depth at which the remains were found. The large supra-orbital ridges of the cranium and its aspect when viewed from above are not unlike characters seen in the Neanderthal calvaria, but these cannot be taken as a proof of the antiquity of the Tilbury skeleton, which, moreover, has a fairly well-developed forehead. The depth (34 feet) at which these remains occurred shows clearly that a long period must have elapsed since they were covered up in the gravel, but this does not amount to a proof of their Palæolithic age.

Mr. T. V. Holmes‡ visited the locality in order, if possible, to determine the age of the gravels and after careful examination came to the conclusion that, although ancient, they were possibly not much older than the Roman embankment, and he says: "The skeleton, therefore, is clearly prehistoric, but the gross exaggeration of age implied by the term 'Palæolithic' is equally obvious." It is just possible that the remains may be Neolithic.

Spy Skeletons (1886).—One of the most interesting discoveries relating to Palæolithic Man is that made by MM. Fraipont and Lohest about ten or twelve years ago at Spy, in Belgium, an account of which they published in 1887, under the title "*La Race Humaine de Néanderthal . . . en Belgique.*"§

Spy is in the province of Namur and the cave is on the side of a wooded hill overlooking the little river Orneau. This cave had been, in part, previously explored and the results published, but outside the entrance there is an extensive terrace, which was systematically examined in August, 1886, with the result that, at the lowest part, human bones were found accompanying the remains of extinct animals.

The human remains represent two individuals, and include parts of the skulls, jaws with teeth, and several bones of the limbs. One of the skulls has its peculiarities more strongly marked than the other, and it is to this one that the following remarks more especially refer. The great peculiarity of the cranium is its near approach in form to that from the Neanderthal. The brow ridges are very strongly developed, although they are not so large as in the last-named specimen, and the receding

* *Archiv. de Biol.*, vol. vii, p. 579.

† *Proc. Roy. Soc.*, vol. xxxvi, 1883, p. 136; also "*Antiquity of Man*," etc., 8vo, 1885, London.

‡ *Proc. Geol. Assoc.*, vol. viii, p. 392, and "*Record of Excursions*," p. 182.

§ *Archiv. de Biol.*, 1887.

forehead is much the same. When seen from above there is a similar narrowness of the frontals behind the orbits and a like inflation of the parietal region. The cephalic index is .70, while that of the Neanderthal calvaria is .73.

The lower jaw is remarkable for the depth of its horizontal ramus, and especially for its receding chin, in both these particulars differing from the usual form in modern human skeletons. The chief peculiarity of the teeth is to be found in the proportionate sizes of the three molars, the hindmost being slightly larger than the two which are in front of it, a characteristic which, as already mentioned, is not usually to be found in modern men, although occasionally present in some savages, but seems to have been much more general among the earlier races of man kind. The limb bones are robust, and the articular extremities large. The femur is arched forwards, and rounded in section, while all the points for the attachment of muscles are strongly marked. The tibia is short and rounded, not flattened or platycnemic.

The Spy skeletons are believed by MM. Fraipont and Lohest to have been contemporaneous with the Mammoth, and this opinion seems to be very generally accepted.

The various beds of *débris* and clay are thus given by the discoverers :—

	Metres.
A. <i>Débris</i> , fallen from above, and brown Clay	9.5
B. Yellow argillaceous Tufa ... ..	.3
C. Red layer. Many worked flints, fragments of Limestone, Charcoal, and Mammoth tusk ... ..	.6
D. Yellow calcareous Clay passing into Tufa. Immediately below this were the human bones ... ..	.04
F. Brown Clay, sometimes black, with many bones and worked flints	
K. Carboniferous Limestone	

The explorers appear to have exercised great care to prevent any errors, and they are persuaded that the two skeletons, which were found outside the cave at a distance of 2 metres apart and distant about 6 and 8 metres respectively from the entrance to the cave, were deposited at the same time as the stratum in which they were found, and were not the result of subsequent sepulture. But it is certainly remarkable that two apparently entire skeletons should have been found, one of them lying upon its side in a position so frequently adopted in burials, and it is difficult to account for these skeletons being covered up in this position and preserved entire while the remains of the extinct mammals found with them seem to have been more or less scattered.

MM. Fraipont and Lohest are of opinion that these two skeletons are representatives of the Palæolithic race of men living at the same time as the Mammoth, and that the human remains from Canstadt, Neanderthal, Naulette, and some other places, although of uncertain age, are, on account of their

similarity, to be included with the Spy skeleton in what they name the Canstadt or Neanderthal race.

British Palæolithic Human Bones.—Nearly all the human bones which have been found in British caves and other Pleistocene deposits have proved to be of Neolithic or some later date. In most instances evidence has been obtained which has shown the remains to be due to an interment, subsequent to the deposition of the stratum in which they were discovered.

Prof. W. Boyd Dawkins* mentions a single human tooth from Pont Newydd cave, near St. Asaph; and there are two instances from river deposits which seem to me sufficiently well authenticated to justify us in speaking of them as of Palæolithic age.

Bury St. Edmunds Skull.—A fragment of a human skull was found by Mr. Henry Prigg in brick-earth filling a pocket in the Chalk, at Westley, near Bury St. Edmunds, and some account of the discovery was given by him to the Anthropological Society.† Mr. Worthington Smith,‡ appreciating the interest of this piece of skull, published a drawing of it in his book; but the fragment was too imperfect to give any idea of the form of the entire skull, and, unfortunately, the specimen has since been destroyed.

Galley Hill Man (1895).—The second instance of human bones from a British Pleistocene river deposit was made known in 1895,§ but the remains had been found some few years previously by Mr. Robert Elliott in the Palæolithic gravel at Galley Hill, Northfleet.

This gravel occurs at a height of nearly 90 feet above the Thames, and is, at the spot where the skeleton was found, about 10 feet thick; it is part of the high terrace-gravel of this neighbourhood, from which many flint implements of acknowledged Palæolithic type have been obtained, and there is no doubt as to the Pleistocene age of the deposit.

The bones were found at a depth of 8 feet in the gravel and at about 2 feet from the top of the Chalk. There is no doubt as to the bones being *in situ*, for the skull was seen in place by one gentleman (Mr. Hayes), and the limb-bones were dug out by another (Mr. Elliott), and were so fragile that it was quite impossible for them to have been placed there by the workmen.

It will very naturally be asked, may not these bones have been buried in the gravel at a later date? The two gentlemen who saw the bones in the face of the gravel are very positive in saying there was no evidence whatever of the gravel above the remains having been disturbed, as it must have been if this were indeed a burial subsequent to the deposition of the gravel. Both these gentlemen were well acquainted with the Galley Hill pit where the bones were found.

* "Early Man in Britain," p. 192.

† *Journ. Anthropol. Inst.*, vol. xiv, p. 51.

‡ "Man the Primæval Savage," p. 281, 1894.

§ *Quart. Journ. Geol. Soc.*, vol. li, p. 505.

The skull is remarkable for its great length, the cephalic index being calculated as '64 ; it has prominent supraciliary ridges and a receding forehead, like the Neanderthal cranium, but not so strongly marked when viewed from above. The Galley Hill skull is found to have no inflation of the parietal region, and thus differs strikingly from the Neanderthal calvaria, although it is equally narrow behind the orbits. The mandible shows a fairly projecting chin, and is unlike the jaws from Spy and Naulette, while the molar teeth resemble those of the former in being nearly of equal size, the last molar not being small as in modern, and especially in civilised, races. The limb-bones present no marked peculiarities, and indicate a stature of but little over five feet.

The Palæolithic age of this skeleton has been questioned by some eminent Anthropologists; but while admitting that absolute proof of its antiquity is not possible, the evidence for it seems to me to be quite as strong as in the case of the Spy skeletons; indeed, I am not aware of any human bones which have a greater claim than these to be accepted as having been coeval with the Mammoth.

I am not satisfied that the Galley Hill skeleton belongs to the same race as the Palæolithic men of Belgium, for although the large supraciliary ridges, low forehead, projecting proboscis, low cephalic index, and large, equal-sized molar teeth are points of agreement with the Spy skeletons, yet the want of inflation in the parietal region, the small mandible with projecting chin, as well as the more normal character of the limb-bones, are unlike the corresponding parts in the Spy skeleton.

Dr. Garson has expressed the opinion that the Galley Hill man belonged to the Spy and Neanderthal race; but, if this be so, a wide allowance must be made for variation in this primitive type of man.

Hunstanton Skeleton (1897).—During the latter part of last summer Mr. Trueman Tucker discovered a human skeleton in a bed of gravel at Hunstanton, in Norfolk; and an account of this discovery was given in a local newspaper by Dr. Jonathan Hutchinson.

There is no room for doubt as to the remains having been found in place. These gentlemen were quite satisfied that "the skeleton was not that of a body introduced from above, but that the strata in which it was entombed had been deposited around it as it lay *in situ*. Although little more than 7 feet of sand and gravel lay over it, yet the condition was absolutely unbroken and continuous right and left, with precisely the same features. It was not alluvium, but sand and flints."

With regard to the age of these gravels there is much uncertainty; although they have been noticed by several writers, and were fully discussed by Mr. B. B. Woodward in the PRO-

CEEDINGS of this Association,* their true geological position has never been satisfactorily settled.

The bones are those of an adult of small stature, and, so far as preserved, present no characters indicative of an ancient race.

In my previous address attention was directed to several discoveries of human bones supposed to be of Tertiary age, which could not be accepted as of so early a date—Colle del Vento, Castenedolo, Arezzo, Foxhall, and Calaveras—and there is no good reason for supposing that any of these remains are referable to the Pleistocene period.

The Java "missing link" (1894).—The remarkable skull, teeth, and thigh-bone found by Dr. Dubois in Java, in beds supposed to be of Pliocene age, were considered at some length in my address last year† and although we then came to the conclusion that *Pithecanthropus* could not be taken as evidence of Man in the Tertiary period, yet in all questions relating to the progenitors of primitive Man these Javan remains are of the greatest interest, and in future must take their proper place in any discussion of Man's early ancestry.

In the size of the brain and the shape of the skull *Pithecanthropus*, as we have seen, is intermediate between Man and certain Apes. The resemblance which the skull bears to the Neanderthal calvaria is striking, but all the pithecoïd characters of the latter are exaggerated in the Java skull, in addition to which a far lower intelligence is indicated by the much smaller brain.

If the Java *Pithecanthropus* is to be accepted as a normal representative of a pre-Palæolithic race of beings, then that race must have been of a far lower type than the one to which the men of Neanderthal and Spy belonged, and would, indeed, seem to be the "missing link" for which evolutionists have so long been searching.

If the prevailing ideas of evolution be correct, we should not expect such an ancestor of Man to have lived in the later Pleistocene; that is to say, at the same time as the Palæolithic race, but at a somewhat earlier period. It might be very early in Pleistocene times, or in the still earlier Pliocene; and it is almost certain that to one or other of these periods the Javan deposits, in which *Pithecanthropus* was found, are to be referred.

However interesting these remains may be as indications of a link in the chain of human ancestry, it would hardly be justifiable to class a race of beings with so small a brain in the same species with *Homo sapiens*.

The close agreement between the thigh-bone of *Pithecanthropus* and those of modern human skeletons may be taken as a caution not to expect any very marked distinction between the bones

* *Proc. Geol. Assoc.*, 1885, p. 97.

† *Proc. Geol. Assoc.*, vol. xv, p. 63.

of Palæolithic and living Man, nor to be surprised if even the skulls fail to present us with any definite characters by which we may distinguish them from those of modern races.

Conclusion.—It will be evident from what has been said that a large proportion of the human bones, supposed to be of Palæolithic age, have proved to be either Neolithic or of still more recent origin, while the evidence concerning many others is so scanty as to leave their age altogether uncertain.

In a few instances, however, the evidence as to the finding of the bones is so well substantiated, and of such a character that they are accepted by most writers as the remains of Palæolithic Man. In this category may be placed the skeletons from Spy and that from Galley Hill, as well as the jaw from the Naulette cave, the piece of skull from Bury St. Edmunds, and perhaps the skull from Eguisheim.

The famous skulls from Neanderthal and Canstadt are among the remains of uncertain age; but on account of their resemblance to the Spy skulls they are supposed to be of the same period and to belong to the same race. If we accept these Spy and other skeletons as remains of the men who made Palæolithic implements, what do they tell us of the mental and physical conditions of those early progenitors of mankind? As a gauge of intellectual capacity, we have to confess that their skulls tell us far less than do the relics of their handiwork.

Professor Huxley,* in speaking of the Spy skeleton, says: "The anatomical characters of the skeletons bear out conclusions which are not flattering to the appearance of the owners. They were short of stature but powerfully built, with strong, curiously curved thigh-bones, the lower ends of which are so fashioned that they must have walked with a bend at the knees. Their long, depressed skulls had very strong brow-ridges; their lower jaws, of brutal depth and solidity, sloped away from the teeth downwards and backwards, in consequence of the absence of that especially characteristic feature of the higher type of man, the chin prominence. Thus these skulls are not only eminently 'Neanderthaloid,' but they supply the proof, that the parts wanting in the original specimen harmonised in lowness of type with the rest."

MM. Fraipont and Lohest,† to quote from Mr. Worthington Smith's‡ translation, in summing up their conclusions say that "having regard merely to the anatomical structure of the man of Spy, he possessed a greater number of pithecoïd characters than any other race of mankind."

"The other and much more numerous characters of the skull, of the trunk, and of the limbs, seem to be all human."

* "Nineteenth Century," Nov., 1890. See also Worthington Smith, "Primæval Man," p. 29.

† *Archiv. de Biol.*

‡ "Man the Primæval Savage," p. 28.

Between the man of Spy and an existing anthropoid ape there lies an abyss."

"The distance which separates the man of Spy from the modern anthropoid ape is undoubtedly enormous ; between the man of Spy and *Dryopithecus* it is a little less. But we must be permitted to point out that if the man of the later Quaternary age is the stock whence existing races have sprung, he has travelled a very long way."

That the Neanderthal and Spy skulls are of a low type no one will deny, and most of us will agree with Prof. Huxley* when he says "Under whatever aspect we view this cranium (the Neanderthal), whether we regard its vertical depression, the enormous thickness of its supraciliary ridges, its sloping occiput, or its long and straight squamosal suture, we meet with ape-like characters, stamping it as the most pithecoïd of human crania yet discovered." Are we then right in assuming that those early men were less intelligent than some of the savages living at the present day? I think not, for in this relation we must bear in mind that the calculated brain capacity of the Neanderthal skull is 75 cubic inches, which is said to be the average capacity of Hottentot and Polynesian skulls. It is quite likely, therefore, that with an equal brain capacity there was a proportionate intelligence. And further than this, it seems that skulls of the Neanderthal type have existed and still exist, among modern, civilised people. Dr. Munro† has called attention to this fact, he says, "At the Paris Congress, M. Vogt quoted the example of one of his friends, Dr. Emmayer, whose cranium exactly recalls that of Neanderthal, and who is nevertheless a highly distinguished lunacy doctor. In passing through the Copenhagen Museum I was struck by the Neanderthal characters presented by one of the crania in the collection ; it proved to be that of Kay Lykke, a Danish gentleman, who played some part in the political affairs of the seventeenth century. M. Godron has published the drawing of the skull of Saint Mansuy, Bishop of Toul in the fourth century, and his head even exaggerates some of the most striking features of the Neanderthal cranium. The forehead is still more receding, the vault more depressed, and the head so long that the cephalic index is .69. Lastly, the skull of Bruce, the Scotch hero, is also a reproduction of the Canstadt type."

It is evident, therefore, that intelligence of a high order may be possessed by a man having a skull like that from the Neanderthal.

With these facts before us we shall be better able to appreciate the force of Professor Huxley's‡ remarks when he says, "In no sense, then, can the Neanderthal bones be regarded as the

* "Man's Place in Nature," 1863, p. 156.

† "Prehistoric Problems," 1897, p. 24.

‡ "Man's Place in Nature," 1863, p. 157.

remains of a human being intermediate between men and apes. At most, they demonstrate the existence of a man whose skull may be said to revert somewhat towards the pithecoïd type."

It is by no means certain that we are right in accepting the Spy and Neanderthal remains as *typical* of the race to which they belong; for it must be remembered that the second Spy skull is less like the Neanderthal calvaria than is the first; and if we accept the Galley Hill man as of the same age and stock, then a wider allowance must be made for variation within the limits of this primitive race than has usually been done.

It is only within the last twelve or thirteen years that the bones of human beings have been found under circumstances which may be taken as reasonable proof of their Palæolithic age. The two Spy skeletons are really the foundation upon which we have to work, and it is only because the Neanderthal, and some other skulls of doubtful age, are like the Spy examples, that they are now referred to the same race.

The Spy and Neanderthal crania are moderately long, having cephalic indices of from '70 to '74, which brings them just within the limits of dolichocephali, and the Galley Hill cranium is among the extremely long skulls, having an index of about '64. It must, however, be remembered that the dolichocephalic skull is not confined to the Palæolithic race, for this is precisely the character which Dr. Thurnam has shown to be a peculiarity of the Neolithic people, and distinguishes them from the round barrow or brachycephalic race of the bronze period.

At present we have too few examples of the skulls of Palæolithic men to allow us to speak dogmatically of their typical characters; but what we do know about them shows that their cephalic index is much the same as in the Neolithic men, from whom they seem to be chiefly distinguished by the greater development of their brow ridges, their low and receding foreheads, and their shorter stature.

The advanced intelligence of Palæolithic Man is abundantly proved by his tools and works of art, which have been preserved in far greater numbers than his bones. The well fashioned flint implements, the striking outlines of the Mammoth, Horses, Reindeer, and human figures incised on pieces of ivory and bone, as well as the clever carvings of animals in these same materials, are ample evidence that the men who lived with the Mammoth possessed no mean artistic ability, and no little mechanical skill.

Sir Wm. Dawson* has shown us how large a part of the works of man perish in a comparatively short time, only those of a very enduring nature remaining to testify to the intelligence of the men who made them. The relics of the ancient inhabitants of Montreal, discovered a few years ago when excavations were

* "Fossil Men and their Modern Representatives," 8vo, London, 1880.

made on the site of the old Indian village, gave no idea of the comparatively high social condition of the people which is known to have existed when the place was first visited by Europeans. These relics might almost have been taken for those of a Neolithic, if not of a more primitive race.

If these facts are kept in mind, there will be a tendency to credit Palæolithic Man with a somewhat higher social status than we have usually supposed him to have enjoyed.

Those who desire a realistic picture of the daily life and habits of primæval Man will find many striking sketches, both with pen and pencil, in Mr. Worthington Smith's "Man the Primæval Savage," and in the Rev. H. N. Hutchinson's "Prehistoric Man and Beast"; but the zeal of my friends, as shown in these works, has carried them into fields of study and regions of scientific imagination whither so prosy a worker as myself is unable to follow.

And now, ladies and gentlemen, I have to thank you for your presence and patience as we have travelled together through this valley of dry bones. I fear lest the feast which I have endeavoured to spread before you may have proved unpalatable and indigestible.

I take this opportunity of thanking you, also, for your willing help and kindly forbearance during the two years that have elapsed since you placed me in this chair. I am conscious of many shortcomings, and had it not been for the friendly and generous support which I have received from all the officers, I fear the Association might have suffered; as it is, I trust its good name is untarnished and its vigour for healthy work at least as great as it was two years ago.

Looking to the future, our prospects are bright. We are sailing over untroubled waters, but we must be prepared for cloud as well as sunshine. Perhaps, before some of us expect it the cry may be raised of "*Rocks ahead!*" and then the presence of a captain who has made such petrological difficulties his special study will be fully appreciated. It is no little satisfaction to be able to resign the duties of the Presidency to one holding so high a position in the geological world as Mr. J. J. H. Teall, who will not only shed lustre on our Association, but in every way enhance its usefulness and strengthen its powers of work.

I have very great pleasure in introducing your new President, Mr. J. J. H. Teall, and, in doing so, hope that to you and to him the coming years may be as pleasant and as profitable as the last two years have been to me.

"The king is dead! Long live the king!"

PEBBLY AND OTHER GRAVELS IN SOUTHERN ENGLAND.

By A. E. SALTER, B.Sc. (LONDON), F.G.S.

(Read March 4th, 1898.)

THIS paper deals with the various High Level gravels of the Thames Valley and the South of England generally. Those on the north side of the Thames Valley have already been described by the author,* and one of the objects of the present paper is to show that the results obtained by a study of the drift gravels of Southern England are in accord with those already published.

PRELIMINARY REMARKS ON GRAVELS AND OTHER FLUVIATILE ACCUMULATIONS.

(a) Gravels, when laid down, were at the lowest level in their immediate district, whatever the position they may now occupy.

(b) The presence of a bed of gravel implies the existence, at the time of its deposition, of a force able to convey material, often of considerable weight,† from a great distance, to its present position.

(c) Denudation acts far more slowly upon strata protected by gravel than upon that which is not so protected. In course of time, the bed of a stream depositing much gravel may become the summit of a hill, owing to the strata forming its banks having been more easily denuded, one large valley being divided into two smaller ones, with a ridge down the centre. In this way *the lines of drainage in one cycle of river action MAY become the water-partings of a succeeding one.* In other cases terraces of varying height may be produced, by means of which a rough estimate of the comparative age of the gravel can be obtained, which estimate, in rare cases, may be further strengthened by the finding of remains of animals, among which may occur indications even of man himself.

(d) The constituents of a gravel often give a clue to the tract of country which furnished them, and enable us to correlate various scattered deposits, especially when considered in connection with the altitude of, and angle of slope between, the various patches of gravel. In the absence of palæontological evidence, this method of correlation is the best available. The size and condition of the components of a gravel give indications of the force operating and the distance travelled.

* "Pebble Gravels from Goring Gap to the Norfolk Coast," *Proc. Geol. Assoc.*, vol. xiv, pp. 389-404.

† Cf. Mr H. W. Monckton's paper "On Some Gravels of the Bagshot District," read before the Geological Society on January 19th, 1898.

MAY, 1898.]

(e) Gravel accumulates in streams chiefly where, for some reason, the current is checked—*e.g.*, when a tributary enters the main stream, in which case there is often a mingling of two distinct classes of constituents. It is quite possible for a small stream, acting for a long time, to deposit a considerable amount of gravel, although at any one time it may be carrying but a few stones. The effect of denudation in a case like this would be to leave the gravel as an isolated patch.

(f) The character of a gravel, whether stratified, unstratified, or contorted, the occurrence in it of sandy or other patches, the kind of matrix, if any, and the condition of the uppermost layers of the underlying beds, all help us to form some idea of the conditions under which the gravel was deposited.

(g) Owing to slipping, redeposition, etc., it is advisable to take the *highest* point in a bed of gravel when forming any deductions based on difference of level. Allowance must also be made for any earth movements which may have occurred since the deposition of the gravel in the area under consideration.

(h) The highest and presumably oldest gravel beds, while themselves subject to addition and alteration, have supplied some, if not all, the materials of the lower and more recent beds of gravel in their vicinity.

(i) Beds of gravel may consist of the sweepings of an area which, after being gently denuded for ages, is subjected to more severe conditions for a time. As an instance of this may be mentioned the occurrence of large boulders* (*e.g.*, sarsens) and flint implements† *at the base* of beds of gravel.

(j) During the excavation of a valley by a river system, the main and tributary streams will frequently alter their positions; but some idea of their former courses will be afforded by the existing beds of gravel left high above the present streams, owing to the differential denudation referred to in (c). It follows from this that gravels deposited by the main stream during the earlier stages of valley excavation may now be found at some distance on one or the other side, *e.g.*, Dartford Heath, Ashley and Bowsey Hills, Hampstead Heath, etc.

(k) Since the effect of denudation is to lower the source of a river while the sea level at its mouth remains practically constant, the several gravel terraces will each have a smaller angle of slope than the one immediately above it. At the same time the relative distances between them in any particular district would be fairly constant.

(l) Neighbouring valleys or river systems in which the climatal conditions are similar, should, allowing for the differences in rock texture, be similar also in the evidence they show

* As at Chobham ridges.

† As at Broom, Somerset; Wrecklesham, Surrey, etc.

of former denudation. Should one valley be more affected than the other, the existence of the denuding agent in greater force might be inferred. Correlation between the drift stages of one valley with those of another may thus be possible.*

THE THAMES VALLEY GRAVELS (SOUTH SIDE).

1. High Level or Early Drifts.

At the following places, patches of gravel are found resting on Tertiary outliers (which owe their preservation to the super-incumbent drift deposits), at heights varying from 400 ft. O.D. near the middle of the valley, to over 600 ft. O.D. on its margin :

(a) Cobham Park, Kent,† near the Mausoleum, 400 ft. O.D.
 (b) Swanscombe Hill, near Northfleet, 300 ft. O.D.‡
 (c) Around Ash on the Plateau near Eynsford and Ightham.
 (d) Well Hill, near Halstead, 600 ft. O.D. This small deposit contains Tertiary pebbles, subangular and green-coated flints, chert, small quartz pebbles (dull, translucent, and pink), jasper, etc. It is situated opposite the gap of the Darent through the North Downs.

(e) Hill above Farningham, Kent.
 (f) Shooter's Hill, 424 ft. O.D.
 (g) West Ho Hill, Norwood, 360-380 ft. O.D.
 (h) Chipstead, over 500 ft. O.D., in pockets overlying the sands found there. The gravel is almost entirely made up of Tertiary pebbles.

(i) St. Anne's Hill, near Chertsey, 300 ft. O.D.
 (j) Burgh Heath.§
 (k) Headley Heath,|| 600 ft. O.D.
 (l) Juniper Hill, 600 ft. O.D. The valley leading up from the Vale of Mickleham to Headley has much gravel on its highest slopes.

(m) Ranmore Common, 600 ft. O.D., on the opposite side of the Vale of Mickleham.

(n) Netley Heath,¶ over 600 ft. O.D. On the left side of the road, running from East Horsley to Shere, is a sand-pit, where about 12 ft. of sand is worked. Above the sand, and in pockets, is a gravel containing rounded, porous, and compact chert, iron-

* For further remarks on this subject see "The Development of Certain English Rivers," by Prof. W. M. Davis, of Harvard University, *Geog. Journal* for Feb., 1895.

† For descriptions of this and several other localities see Prof. Prestwich's papers on the "Southern Drift," etc.

‡ Cf. "Excursion to Swanscombe," *Proc. Geol. Assoc.*, vol. xiv, p. 305.

§ Cf. "Notes on the Gravels of Croydon and its neighbourhood," by G. Jennings Hinde, *Trans. Croydon Microscopic and Nat. Hist. Club*, 1896-7.

|| Cf. "Excursion to Headley," *Proc. Geol. Assoc.*, vol. xiv, pp. 124-128, by H. W. Monckton.

¶ *Proc. Geol. Assoc.*, vol. x, p. 182; also "On the Sands and Ironstones of the North Downs," by Prof. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xiv, pp. 321-335; "Geology of the London Basin," W. Whitaker, vol. iv, pp. 336-342; and *Quart. Journ. Geol. Soc.*, vol. xviii, p. 271 et seq.

stone pebbles (polished and containing small pebbles of flint and quartz), unworn flints, small quartz, Tertiary pebbles, sandstone, and pieces of marcasite nodules. Quite close to the pits, and probably derived from them, was a large sarsen

(o) Newland's Corner, near Guildford, nearly 600 ft. O.D.

(p) Upper Hale, near Cæsar's Camp,* Aldershot, 470 to 605 ft. O.D. The upper part of the deposit is far more sandy than the lower, in which several sarsens are embedded in a clayey matrix.

Some of the foregoing consist of Tertiary *débris* only and were derived from strata previously existing in the Thames basin; others, however, contain material from a wider area, *e.g.*,

(a) Chert, which may be of a white, brown, or red colour, and either porous or compact. This is derived from the Lower Greensand area, and, together with other material mentioned later, show that the drainage area of the Thames has been curtailed towards the south.†

(b) Ironstone. Three distinct kinds are met with in the above localities, viz., a compact variety, evidently derived mediately or immediately from the Wealden area; a coarser variety, containing well-rolled flint pebbles, pieces of quartz, small flakes of mica, etc., which must therefore be of post-Cretaceous age, and is probably derived from pre-existing Pliocene beds on the North Downs; and a rougher variety, derived probably from the Bagshot sandy beds.

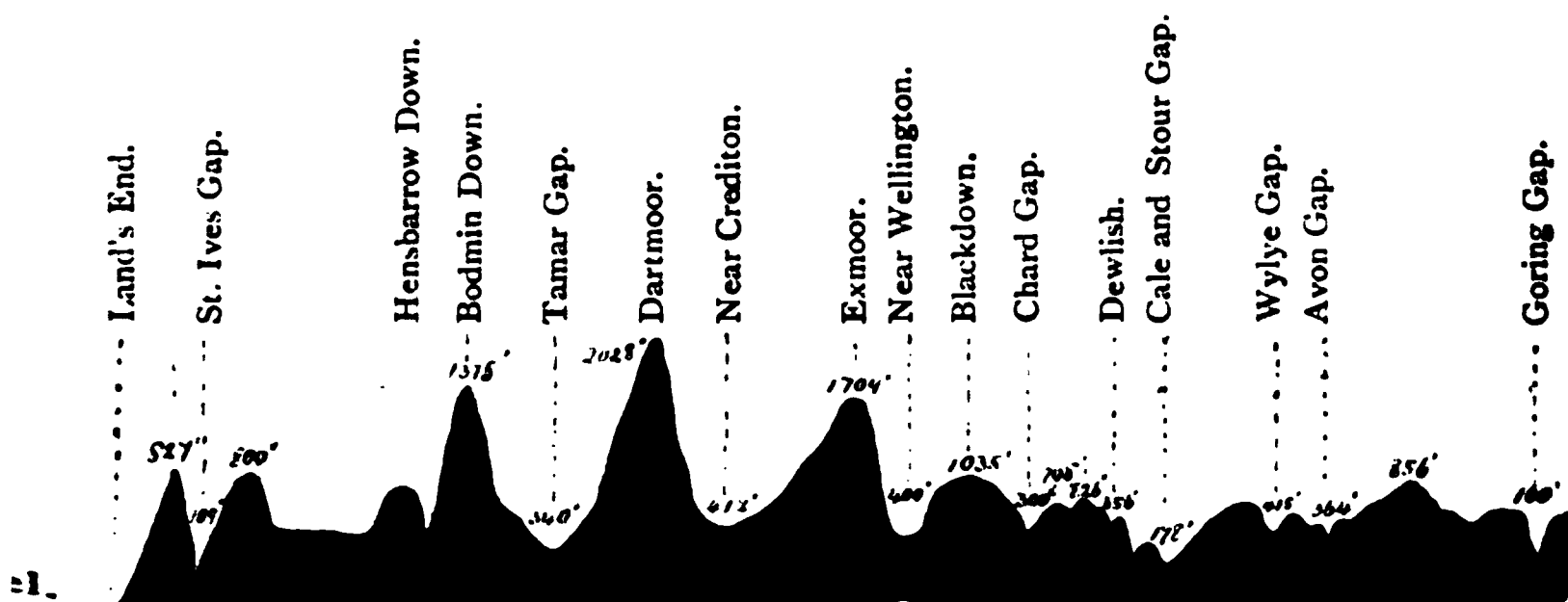
(c) Small quartz pebbles. These vary in size from half an inch long to sand, and consist of the dull, translucent, and pink varieties. Similar quartz pebbles occur in layers in the Wealden sandstones, *e.g.*, those at Tunbridge Wells, near which place Dr. Abbott has found small pebbles of jasper, quartz, sandstone, etc., associated with them. These quartz pebbles are quite distinct from those found in the Westleton Drift on the north side of the Thames Valley, excepting those found on Hampstead Heath.

It would appear, therefore, that this series of deposits was laid down while the southern slopes of the Thames Valley were still mantled by Tertiary deposits, and when these slopes continued without break to the Wealden area. At first beds of gravel, made up of the wreckage of Tertiary beds, would be deposited, but soon material from a greater distance would appear as the streams deepened and cut back their channels, or earth movements brought the lower strata under the influence of denuding agents. The harder Chalk range would be breached at a few points by the streams running northward from the Weald, and thus initiate the series of gaps in the North Downs.

* Cf. H. W. Monckton "On the Gravels South of the Thames from Guildford to Newbury," *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 30, etc.; also Prof. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xlv, p. 161; and Dr. Irving in *Proc. Geol. Assoc.*, vol. viii, p. 143.

† Cf. F. G. Spurrell, "A Sketch of the History of the Rivers and denudation of West Kent," *Proc. West Kent Nat. Hist. Soc.*, Jan. 27, 1886.

In the east the Darent commenced, and deposited the Well Hill and other gravels of West Kent. In the west several smaller streams appear to have fed a larger one which flowed westward close to Burgh, Headley, and Netley Heaths, towards the Merrow Downs and Upper Hale, Aldershot.* High land, above 600 ft. O.D., must then have existed over the Bagshot country, and prevented the streams flowing direct north as the Mole and Wey do now. This range supplied the sarsens from its upper portions since, at Upper Hale, we first find them embedded in the gravel near the base. The presence of this range would enable us to account for the curious sands associated with the gravels at Netley and Headley Heaths as being drifted from it in the higher courses of the tributaries of the main east-to-west stream. I shall hereafter refer to this high land as the Bagshot sarsen range, and to the main stream flowing east to west as the Bagshot



2.—SECTION ALONG THE HIGHEST GROUND BETWEEN GORING GAP AND THE LAND'S END (*Vertical Scale much exaggerated.*)

stream, since they are both intimately connected with the past history of the Bagshot country.

Further to the west, the gravels near Inkpen (Upper Kirkby Green, 573 ft. O.D.) and Hungerford on similar Tertiary outliers, and the Southern Drift at Snelsmore and Greenmore Commons, 440 ft. O.D., near Newbury,† seem to point to a stream from the west, while on the north side of the valley a very similar set of gravels are met with. The "A" series, described by the author, corresponds to the drift containing local materials only, while closely connected with it is a series of gravels containing material derived from a distance. These were included in the "C" series, or Westleton Drift proper. The series "B" of that paper, the author thinks, was mainly derived from the south.

Before the succeeding series of gravel deposits were laid down, a vast amount of denudation took place. Some of the streams which brought quartz pebbles, etc., from the Wealden area were

* Cf. H. W. Monckton's remarks, *Proc. Geol. Assoc.*, vol. xiv, pp. 124-128.

† Cf. P. E. Richards in *Quart. Journ. Geol. Soc.*, vol. liii, p. 420.

diverted owing to the formation of the Chalk escarpment and the longitudinal E. and W. valleys at its base. Those traversing the Chalk range greatly deepened their channels and the sides of the Downs became furrowed by what are now dry Chalk valleys. The valley of the Darent became restricted to Lower Greensand and younger strata, while the Bagshot stream appears to have lost its upper feeders (the Mole, etc.), which flowed more directly northward to the central main stream.

Recently Mr. Clement Reid* has put forward the view that the removal of the flints from the Chalk has been brought about by the porous Chalk being temporarily converted into a hard compact rock by being frozen. This is quite feasible, and would most effectually lead to the sweeping of the hard insoluble residue from the Chalk down the valley. It is quite possible, however, that flints were not abundant. At Wrotham Chalk-pit, in the face of the escarpment, they are very scarce now. Beside this it is well to notice that in the formation of these transverse and dry Chalk valleys, we are dealing with a rock which under certain conditions is soluble in water. The solubility of calcium carbonate in water depends on the amount of carbon dioxide present, and the amount of this substance depends on temperature and pressure. The latter need not be noticed as the action we are considering took place at the surface. The former, however, is important. More carbon dioxide is taken up by cold water than by hot. It follows, therefore, that the amount of soluble bicarbonate of lime produced depends upon the temperature. For this and other reasons mentioned later, it is highly probable that the transverse and dry Chalk valleys were formed during a period when very cold water was continually acting upon the Chalk. In the more northern parts of England the Glacial period has mainly left its mark in the various effects of *solid* ice, in the south the effects are those of *liquid* water. This would lead to great denudation in the warmer portions of the country since the ice further north remaining longer unmelted would act as a rock, possibly cause great deviations in the lines of drainage, and certainly cause those which lead south to become inordinately swollen.

It is interesting to note that those parts of the North Downs† on which these drifts occur have been subsequently denuded the least, and it is there that Mr. B. Harrison and others have found those remarkable chipped flints (eoliths) described by the late Prof. Prestwich. Rolled specimens of them are found in the next series of gravels. It seems probable that these implements were scattered on the surface during the interval between the High Level and Lower Plateau Drifts.

* *Quart. Journ. Geol. Soc.* vol. xlviii, p. 360.

† For other localities, etc., cf. A. S. Kennard on "The Authenticity of Plateau Man," "Nat. Science," vol. xii, p. 277, and the Rev. A. Bullen in "Nat. Science," vol. xii, p. 106; also "Excursion to the Kentish Plateau," W. J. Lewis Abbot, *Proc. Geol. Assoc.*, vol. xiv, p. 196.

2. Lower Plateau and Glacial Drifts.

This series of gravels has a closer connection with the present river valleys than the preceding. It will be convenient to take the deposits in the tributary valleys first, and then those more directly connected with the main stream.

(a) In the Darent Valley, which was so thoroughly investigated by the late Prof. Prestwich, deposits occur at

1. Limpsfield Common,* above 500 ft. O.D.
2. Farley Hill, two miles E. of the Limpsfield patch, and 450 ft. O.D.
3. Boughton Hill, near Dunton Green, 357 ft. O.D.

The gradient given by these patches is 25 ft. per mile, which, if continued down the valley, would coincide with the level of the Dartford Heath gravel, which consists of material derived from the south, mingled with northern material.† Since the Limpsfield gravel is on the watershed of the Darent, and consequently at the top of the slope indicated, it is possibly rather older than the others, as may be inferred from the type of implements found there.

The gravels at Dunton Green and Chevening, in the Darent Valley, at slightly lower levels, 270 ft. O.D., than those already mentioned, appear to indicate a second stage, and the Chevening gravel is interesting, since it shows contortion, which also occurs in the Clay Pit on Limpsfield Common.

(b) The Wandle Valley, which at an early date was deprived of its Wealden drainage area by the recession of the Chalk escarpment northward and the cutting back of their valleys by the upper feeders of the Mole and Medway,‡ contains, as far as I know, nothing equivalent to the gravels at Limpsfield, unless those at Foxley Wood, 350 ft. O.D., and others near Caterham Junction, a few feet lower, mentioned by Mr. Spurrell,§ should be placed with them. Dr. G. J. Hinde, in an exhaustive account of the gravels of this valley, makes no reference to anything equivalent.|| The Chalk pit at Purley formerly showed numerous pipes filled with an ochreous gravel, which might possibly be referred to this stage.

(c) The Bagshot District. The gravels connected with the basins of the Mole, Wey, and Blackwater, will be considered together, the soft Bagshot strata having suffered greatly from denudation during and after this period.

Owing to the researches of Mr. H. W. Monckton, Dr. Irving,¶

* Cf. W. Topley, *Proc. Geol. Assoc.*, vol. xi, p. 32.

† For other patches in the Darent and Cray valleys mentioned by Prof. Prestwich, see *Quart. Journ. Geol. Soc.*, vol. xlv, pp. 270 *et seq.* (especially the diagram on p. 272) and vol. xlvii, p. 126.

‡ W. Topley, "Geology of the Weald," *Geol. Survey Memoir*.

§ F. G. Spurrell. *Op. cit.*

|| *Op. cit.*

¶ "On Bagshot Strata of the London Basin and their Associated Gravels," *Proc. Geol. Assoc.*, vol. viii, pp. 143-171.

Prof. Rupert Jones, and many others, the gravels of this district have received a great deal of attention, and I shall merely state such facts as are necessary, in my opinion, to show their position in connection with the other gravel deposits of the South of England. The Bagshot sarsen range still persisted, though probably of much less altitude, and continued to contribute large sarsens from its upper beds to the Bagshot stream which flowed along where the Chobham and Frimley Ridges and East-hampstead Plain, 426-390 ft. O.D., now remain. The bulk of the material composing the gravels in this district is derived from Tertiary strata, and but little from the Wealden. This is another indication that high ground composed of Tertiary strata existed to supply it. As denudation proceeded, this line of drainage became a watershed between the Bagshot stream flowing N.W. to join the main stream, and another flowing N.E. to join the same stream at a point nearer its mouth. By the first of these, the Hartford Bridge Flats and Finchampstead Plain gravels would be laid down at levels varying from 300 ft. to 333 ft. O.D., while the other would deposit the patches mentioned by the authors named, at Windlesham 310 ft. O.D.; the hills above Ascot, 301 ft. to 320 ft. O.D.; Chavey Down, 302 ft., etc. It is interesting to note that only small, rolled pieces of sarsen are found in the Hartford Bridge Flats gravels to the west of the ridges, while at Ascot Heath (especially near the Royal kennels) and St. George's Hill, 245 ft. O.D. to the east, they are large and plentiful.* From this it would appear that the sarsens came mainly, if not wholly, from the East side of the Bagshot stream.

The gravels further west contain no chert, and but very few quartz pebbles. They are referred to the "Silchester type," by Mr. Monckton, and belong, I think, to another stream altogether, which drained the area on the western side of the Bagshot stream watershed, and correspond to the High Level Drift in that area in a similar manner to that in which the Chobham ridges, etc., do to the gravels at Upper Hale, etc. Mr. P. E. Richards describes a gravel 300 ft. O.D. at Donnington Grove, Newbury, which belongs to this stage †

In this district, then, there are distinct indications of two stages during this period, with a difference of about 100 f between them.‡ Mr. O. Shrubsole§ has found rudely chipped

* Cf. H. W. Monckton, *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 42. See also Dr. Irving in 'Science Gossip' for May and June, 1891, and *Proc. Geol. Assoc.*, vol. viii, pp. 143-171; and W. H. Hudleston, *Quart. Journ. Geol. Soc.*, vol. xlii, p. 147.

† "Gravels and Associated Deposits near Newbury," *Quart. Journ. Geol. Soc.*, vol. liii, p. 420.

‡ Cf. Prof. Rupert Jones in *Proc. Geol. Assoc.*, vol. viii, p. 442; and Dr. A. Irving "On the Bagshot Strata of the London Basin and their Associated Gravels," *Proc. Geol. Assoc.*, vol. viii, p. 143-171.

§ "On Flint Implements of a Primitive Type from old (preglacial) Hill Gravels of Berkshire," *Journ. Anthropological Inst.*, vol. xxi, p. 241; and *Quart. Journ. Geol. Soc.*, vol. xlix, p. 320.

flints in these gravels, and most suspicious-looking specimens have been obtained by the author from the Chobham Ridge Plateau at High Curly, near Bagshot.

(d) The main stream (Thames). In the central portions of the valley are found several gravel deposits corresponding in level to the preceding, containing, in addition to the materials already described as coming from the South, a quantity of other material derived from the North, and probably also some from the West of England. They mark the position of the confluence of the Southern streams with the main one at that time. Dr. Buckland* and Prof. Phillips showed that Triassic *débris* entered the Upper Thames Valley through the gaps at Moreton in the Marsh,† and above Banbury. An admirable summary of former work on this part of the subject has recently been laid before the Association by Mr. Osborne White.‡

The characteristic constituents of these gravels are quartzites of various colours, quartz, grits, radiolarian chert, schorl-rock, jasper, and igneous rocks. The chief localities where these deposits occur are :

(1) In Oxfordshire, near Moreton, Wightam and Bagley Woods, the high parts bordering the Evenlode and Cherwell valleys, at heights above 500 ft. O.D. (2) Around Goring Gap at Upper Basildon, 426 ft. O.D. ; Tilehurst, 290-341 ft. O.D. ;§ The Hockett, near Quarry Woods, 351 ft. O.D., and Littleworth Common on the opposite side of the river ; Shiplake, 340 ft. O.D. ; Cookham Dean, 300 ft. O.D.|| (3) The Mount, Ealing, 210 ft. O.D. (4) Kingston Hill, Coombe Wood,¶ 178 ft. O.D. ; Richmond Hill, 181 ft. ; Wimbledon Common, 180 ft. (5) Dartford Heath,** 136 ft. Rolled *Gryphæa*, brown, light coloured, and variegated quartzites, quartz pebbles, schorl-rock from the W. and N. and chert, ironstone, flint, etc., chiefly from the S., occur here. The gravel is 10-20 ft. deep on the Heath ; but at Wansunt Pit, near Crayford Station, it is 40 ft. thick.

During this period Goring Gap was apparently further deepened in two stages,†† during the first of which the gravels on Ashley and Bowsey Hills were deposited, and the remainder of the deposits rather later. The influx of water, etc., from the Bagshot stream led to the deposit of much material in the Reading and Maidenhead districts, and, as far as I am aware, no

* "Reliquiæ Diluvianæ," p. 279, etc.

† This gap is now 420 ft. O.D.

‡ "On the Origin of the High Level Gravel with Triassic *débris* adjoining the Valley of the Upper Thames," *Proc. Geol. Assoc.*, vol. xv, p. 157.

§ See "Valley Gravels near Reading," by O. Shrubsole, *Quart. Journ. Geol. Soc.*, vol. xvi, p. 582.

|| "On the distribution and relations of the Westleton and Glacial Gravels," *Proc. Geol. Assoc.*, vol. xiv, p. 11.

¶ "Visit to Great Gravel-pit South of Warren House," *Proc. Geol. Assoc.* vol. vi (1880).

** "Excursion to Dartford Heath" *Proc. Geol. Assoc.*, vol. xiii, p. 70, by F. G. Spurrell.

†† The stream depositing the Westleton Drift had already cut down a considerable depth.

similar deposits are found corresponding in height for some distance. This will be explained if we remember that the next tributary, draining what is now the basin of the Mole and part of the Wey, had not joined the main stream. The gravels at Kingston Hill, probably mark the position of this confluence. Not only the character of the larger constituents testifies to the correctness of this view, but the sandy matrix is evidently derived from the green, sandy beds in the Bagshot area.* The gravels at The Mount, Ealing, described by Mr. Allen Brown,† stand at another such junction; in this case probably with a stream flowing southwards from the northern Chalk range, and they may be connected with the deposits at Harefield and St. Albans. Further east another important stream from the north joined the main stream, by the Hitchin and other gaps, which deposited the Finchley and Oakleigh Park gravels, containing *Gryphæa*, etc. The gravels at Hendon,‡ described by Dr. Hicks, containing sarsens, porous and compact chert, and other southern drift material, may have been laid down by the main stream at and near its junction with that coming *viâ* the Hitchin and other gaps. The stream passing through Bishop's Stortford Gap also yielded its *quota* of foreign material to the main stream.§ The next important tributary was the Darent, and at its junction with the main stream the Dartford Heath|| and other gravels, at similar heights in the neighbourhood, were deposited. These gravels, although now South of the Thames, contain northern *débris*, some of which can be traced through the Hitchin and Bishop's Stortford Gaps (*e.g.*, *Gryphæa*, *Belemnites*), and cannot be found in deposits higher up the main valley.

No contemporaneous fossils, such as large mammalia, have been recorded from this set of gravels, and in this respect they differ from gravels at lower levels. Rude Palæoliths and rolled Eoliths are found in the Darent gravels, in the Bagshot stream, and quite recently by Mr. Llewellyn Treacher,¶ at the Hockett, near Goring Gap.

This series corresponds to the series D and E (two stages) of the author's previous paper.

* *E.g.*, those seen during the recent Excursion to Woking. *Proc. Geol. Assoc.*, vol. xv, p. 185.

† "The Thames Valley deposits of the Ealing district," by J. A. Brown, *Quart. Journ. Geol. Soc.*, vol. xlii, p. 192; also "Excursion to the Mount, Ealing," *Proc. Geol. Assoc.*, vol. x, p. 361, and vol. xiv, p. 153.

‡ "On some recently exposed sections in the Glacial Deposits at Hendon," by H. Hicks, *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 575; "Excursion to Hendon," *Proc. Geol. Assoc.*, vol. xiv, p. 328.

§ "Excursion to Bishop's Stortford," by Dr. A. Irving, *Proc. Geol. Assoc.*, vol. v, p. 193; and Dr. Gregory, "Excursion to Walthamstow," *Proc. Geol. Assoc.*, vol. xii, p. 339—

|| "Excursion to Dartford Heath," *Proc. Geol. Assoc.*, vol. xiii, p. 79.

¶ *Proc. Geol. Assoc.*, vol. xv, p. 101.

3. The River Drifts.

Below the High Level Drift and Lower Plateau Gravels, are several gravel deposits which are distinguished from them by their lower level, their closer connection with the present valleys, and by the bones of extinct mammalia and Palæolithic implements often found in them. They are all, in my opinion, newer than the latest of the Glacial deposits in the valley, viz., the Chalky Boulder-Clay, which can be seen resting on the Lower Plateau gravels in the Lea Valley at Hatfield Hyde,* in the Stort Valley, near Hockerill,† in Herts, on the Hendon Plateau,‡ at Whetstone§ and Oakleigh Park,§ near Finchley, etc.; and Mr. T. V. Holmes has shown|| that this same deposit *underlies* the *highest* river terrace at Upminster. As before, it will be convenient to take the tributary valleys first, and then the main one.

(a) The Darent and Cray.

Remains of *Elephas* have been found at Shoreham and Otford. In the neighbouring Cray valley, gravel beds occur at Pratt's Bottom, where there is a small pit of flint gravel with a capping of 4 ft. of soil. Quite close were large pieces of pebbly ironstone, obtained from similar pits, but evidently drifted down from the higher ground. Lower down the valley are large pits with great flints and pieces of ironstone, while still lower down (276 ft. O.D.) at Green Street Green is a pit 20 feet deep of a similar character¶ which has yielded *Elephas primigenius*, Blum., Rhinoceros, Musk Ox, etc. Further west, near Hayes Station and on the left of the road leading to West Wickham, are pits in similar gravel 11 ft. thick. It is an ochreous gravel, containing large flints, some but little worn, flint pebbles, ironstone, and a good-sized block of pebbly conglomerate.

(b) The Wandle Valley.

Dr. Hinde** has recently published an account of the gravels of this valley. They all belong to the series we are now considering. Flint implements occur in the neighbourhood of Thornton Heath.†† Near Upper Warlingham Station are large pits, from which I was shown a tooth of *Elephas* obtained at a depth of 12 ft. The gravel consists almost entirely of flint, with small pieces of ironstone, but I saw little or no chert or flint pebbles. Just behind a farm, near the old bourne, was a gravel containing flints up to 1 ft. × 1 ft., marcasite nodules, blocks of rolled conglomerate (2 ft. × 1 ft. 9 in.) and

* Visited by the Association on May 14, 1898.

† "Excursion to Bishop's Stortford," and also "The Geology of the Stort Valley," *op cit.*

‡ *Proc. Geol. Assoc.*, vol. xii, p. 3, 4.

§ "Excursion to North Finchley and Whetstone," by Dr. Hicks, *Proc. Geol. Assoc.*, vol. xiii, p. 367.

|| *Proc. Geol. Assoc.*, vol. xii, pp. 316-319.

¶ "Excursion to Down," *Proc. Geol. Assoc.*, vol. xii, p. 393

** *Op. cit.*

†† I obtained one fine specimen nearly 8 in. long.

small Tertiary flint pebbles. Quite recently *Rhinoceros antiquitatis*, Blum., and *Elephas* have been obtained near Carshalton.*

(c) Bagshot Country. Prof. Rupert Jones long ago † recognised that three distinct ledges or benches of gravel occurred between the Chobham ridges and the Blackwater, and Mr. H. W. Monckton, in the section he draws from Farnham Park to the River Blackwater, ‡ recognises three series of gravel deposits below the Hartford Bridge Flats gravels, and again, on the East side of the Chobham ridges in his section from them to the Hale Bourne, two deposits at 200-224 ft. O.D.§ and 102 ft. O.D. are recognised. In a paper by the same author on the Farnham district|| a section is given from Upper Hale to Wrecklesham, where three divisions below the Lower Plateau Gravels are apparent. The highest of these, viz., that at Wrecklesham 360-380 ft. O.D. and 25 ft. thick, is extremely interesting as being the patch from which Mr. Mangles and Mr. F. Lasham¶ obtained such a large number of Palæolithic implements, the majority of which, it should be noted, come from near the bottom of the gravel. The direction, N.W. to S.E., height, composition, and stratified character of this deposit, mark it as having been deposited by the Bagshot stream after the deposition of the Hartford Bridge Flats gravels.

Dr. Hicks recently referred to the finding of remains of *Elephas primigenius* and *Rhinoceros* resting on the London Clay between Hendon and Edgware,** and, again, Mammoth, etc., at 80 ft. O.D. at Endsleigh Street, †† London.

Further down the main stream the classical deposits at Crayford and Ilford might be cited, together with the remarkable discovery of human bones and implements made by Mr. Elliott at Galley Hill. ‡‡

HANTS AND DORSET.

Corresponding to the synclinal fold known as the London Basin, the gravels of which we have just considered, there is in the South of England another and roughly parallel example, due probably to the same series of earth movements, running from the neighbourhood of Dorchester to Brading in the Isle of Wight. The river Frome drains the upper portion of the valley

* Cf. W. W. Watts at Meeting of the Geological Society, November 3rd, 1897, *Quart. Journ. Geol. Soc.*, vol. lv, p. ii.

† *Proc. Geol. Assoc.*, vol. viii, p. 442, and vol. vi, pp. 329 and 429.

‡ *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 31.

§ The large spread of gravel at Walton Common at 100 ft. O.D. and 145 ft. below St. George's Hill, probably should be placed here. Cf. W. H. Hudleston *Quart. Journ. Geol. Soc.*, vol. xlii, p. 147 *et seq.*

|| *Proc. Geol. Assoc.*, vol. xiii, pp. 74-81.

¶ Cf. "Palæolithic Man in West Surrey," by F. Lasham, in *Coll. Surrey Arch. Soc.*

** See *Quart. Journ. Geol. Soc.*, vol. liv, p. ii.

†† "On the discovery of Mammoth and other remains in Endsleigh Street," etc., *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 453.

‡‡ See *Proc. Geol. Assoc.*, vol. xiv, p. 305, and *Quart. Journ. Geol. Soc.*, vol. li, p. 72.

thus formed, the lower portion having been denuded by the sea.*

The gravels of this area are as follows :

1. High Level or Early Drifts occur :

(a) In the Isle of Wight, on St. Boniface Down, St. Catherine's Hill, and other places, an angular flint drift is found. In a few places Tertiary flint pebbles and quartz can be obtained.†

(b) On the water-parting between the Thames and the streams flowing into Southampton Water, at Meadstead, 650 ft. O.D. Mr. S. V. Wood records a drift 20 ft. deep, consisting of large water-worn flints mixed with loam.‡

(c) On the highest points of the hills overlooking Weymouth and at Portisham on Blackdown, there is a good section close to Hardy's Monument, 777 ft. O.D. Like the two previous examples, it is on the watershed of the Frome. The deposit is from 15 ft. to 20 ft. thick, and contains, among others, the following : well rolled Chalk flints, Tertiary pebbles, white and pink quartz pebbles up to 2 in. \times $1\frac{1}{2}$ in. (abundant) jasper (comparatively plentiful), porous chert, dark chert, pieces of schorl-rock, fragments of reddish, glassy quartzites, etc. Mr. Clement Reid§ regards these as of Bagshot age, coupling with them some lower sands and gravels 146 ft. O.D. at South Moreton, about 12 miles N.E. The similarity in composition between these gravels and others to the west, leads me rather to regard them as belonging to a previous cycle of river action, and to have been derived from a source further west.

2. Lower Plateau Drifts.

Both in Hampshire and the Isle of Wight a distinct series of gravels, similar to those in the Thames basin, are found sloping on either side toward the main channel.|| They consist chiefly of flint, both unworn, subangular, and as pebbles, Greensand-chert, ironstone, quartz pebbles, and blocks of greywether sandstone, a very similar mixture to that of the Thames area.

Two stages appear to exist in the high ground bordering the Test valley and Southampton Water, which district has come more particularly under my observation. In the neighbourhood of Romsey the Plateau gravels are found at heights between 300 and 242 ft. at the Tower of Winds, Chilworth, where they are

* See "On the Physical History of the Isle of Purbeck," by A. Strahan, *Proc. Geol. Assoc.*, vol. xiv, p. 405.

† *Mem. Geol. Survey*, "The Isle of Wight," 2nd edition, p. 208, etc.

‡ "The newer Pliocene in England," by S. V. Wood, *Quart. Journ. Geol. Soc.*, vol. xxxviii, p. 667.

§ "The Eocene deposits of Dorset," *Quart. Journ. Geol. Soc.*, vol. lii, 1896.

|| For full descriptions see "On the superficial deposits of the South of Hampshire and the Isle of Wight," by T. Codrington, Esq., *Quart. Journ. Geol. Soc.*, vol. xxvi, p. 528, and *Memoir Geol. Survey*.

contorted,* and near Shootash and Embly Park.† At Baddesley Common is a bed of gravel 148 ft. O.D., and along the edge of the valley at heights above 100 ft. O.D. similar deposits occur at Green Hill, Pauncefoot Hill, 160 ft., Winchester Hill, Ganger Wood, etc. Two stages are thus apparently present as in the Bagshot area, with a difference of level of over 100 ft. The same thing occurs lower down the valley, on the hills on both sides of Southampton Water, at Beaulieu Heath 133 ft., and Titchfield Common, about the same height.‡

No Palæolithic implements, or remains of large mammals, as far as I know, have ever been found in these deposits. Plateau gravels of a similar nature are recorded from the high ground above the Avon; these attain their greatest elevation at Downton Common, 420 ft. O.D.

At Cams' Wood, near the Nelson Monument, Portsdown Hill, 100 ft. O.D., and near Cowes 130 ft., which would be on or near the main stream at this period, large liver-coloured quartzites, from the New Red Conglomerates of the West, have been found.§ The cliffs between Lymington and Christchurch and again from Hengistbury Head towards Bournemouth, are capped with an ochreous flint gravel with little or no quartz. These are succeeded by gravel of a totally different character, containing besides flint, much quartz, chert, and schorl-rock.|| Similar deposits are also recorded on the road between Bournemouth and Poole at 160 ft. Some of these contain implements and belong to the series to be next described, others may be the southern prolongations of the Plateau gravels. The gravels at Bournemouth are evidently made up of the redeposited materials from the Blackdown (Hardy's Monument) High Level Drift, laid down by the old Frome, at its junction with the Glacial stream from the North.¶ We have here in fact the counterpart of the junction of the Bagshot stream with that from the Upper Thames, bearing the northern drift of Triassic and other *débris*, and there can be little doubt that the climatal conditions necessary for the one were present when the other was deposited.**

It is interesting to note that at a corresponding level (about 350 ft. O.D.) on a ridge forming the high ground between two

* Cf. Dunton Green and Chevening Gravels in the Darent Valley, and St. George's Hill, near Weybridge.

† At Alderbury Hill, 3 miles E. of Salisbury, a similar flint gravel with small quartz pebbles is found at 300 ft. O.D.

‡ See also "On the presence of Raised Beach on Portsdown Hill," by Prof. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xxviii, p. 38, and "Geology of Portsmouth and Ryde," by C. Evans, *Proc. Geol. Assoc.*, vol. ii, p. 170, where similar gravels are described at Bourne Common 142 ft. O.D.

§ Prof. Prestwich also describes in his paper on the Southern Drift, a drift on a Tertiary outlier at Coptord (? Codford), 8 miles E. of Warminster, which contains Tertiary pebbles, white and rose quartz, light sandstone, dark chert, and lydian stone pebbles.

|| See *Quart. Journ. Geol. Soc.*, vol. xxxviii, p. 4, for a section showing these gravels.

¶ It is worthy of notice that the valley of the Avon is connected with a gap in the North which is 364 ft. O.D. at its highest point near Etchelhampton Hill. Cf. Mr. W. H. Bell's remarks, *Proc. Geol. Assoc.*, vol. xii, p. 324.

** See Sir Charles Lyell's remarks on T. Codrington's paper, *op cit.*

recent valleys* and about 90 ft. above the present stream, occurs the remarkable and unique deposit at Dewlish,† in which remains of *Elephas meridionalis*, Nesti, were found associated with flint, quartz, and Palæozoic (? schorl) pebbles. The occurrence of this Upper Pliocene fossil seems to indicate that the period immediately preceding the Lower Plateau drifts may have been Upper Pliocene.

3. The River Drifts.

With the exception of *Elephas meridionalis*, no remains of mammals have been found in the High Level gravels of this valley; but in the lower deposits both implements‡ and bones are met with. In general three terraces are evident, as in the Thames Basin.

The upper part of the Test Valley does not contain much gravel; but after its junction with the Anton, near Dunbridge, there is plenty; and along the last-named river many patches occur.§ At Belbins, about two miles from Romsey and 90 ft. O.D., is a thick gravel patch in which Palæolithic implements occur. Similar gravel occurs at Nursling and below the junction of the Itchen and Test. On the east side of Southampton Water, by Netley, Hill Head, and at Lee-on-the-Solent, thick beds of gravel, containing implements overlain by brick-earth, are seen. Sarsens|| are frequently found in these river gravels, especially at Lee-on-the-Solent. The Bembridge¶ gravels, which occur between H.W.M. and 60 ft. O.D. on the Isle of Wight, correspond in level and composition to them, and were, I think, laid down at the same time. If this be the case, it signifies that the Frome still continued its course uninterrupted beyond the Solent towards what is now Selsea Bill, which was then probably near its mouth. It is here that those interesting deposits of *Elephas*,** etc., in association with southern shells occur, as described by C. Reid,†† Godwin Austen, and others. ‡‡

At about 146 ft. O.D. near South Moreton, 8 miles east of

* The Chalk down to the N. of Dewlish can be crossed at 356 ft. O.D. This probably indicates that a stream passed from N. to S. during this period.

† Cf. "Pliocene Deposits of Great Britain," by C. Reid, *Mem. Geol. Survey*, 1890, pp. 206-208; see also W. H. Huddleston's remarks in his Presidential address to the Geological Society, 1893, vol. xlix, p. 67 *et. seq.* Note Mr. Mansel Pleydell's letter there quoted.

‡ Cf. "Flint Implements of the Hants Basin," Sir J. Evans, *Quart. Journ. Geol. Soc.*, vol. xx, p. 188; also his Presidential address to the Geological Society, *Quart. Journ. Geol. Soc.*, vol. xxxi, p. lxxi.

§ "On the Discovery of Flint Implements in the Drift of Milford Hill, Salisbury," by H. P. Blackmore, *Quart. Journ. Geol. Soc.*, vol. xxi, pp. 250-252. See also *Quart. Journ. Geol. Soc.*, vol. xxviii, p. 38, and T. Codrington's paper previously quoted.

|| Cf. *Geol. Mag.*, vol. iii, p. 296.

¶ *Quart. Journ. Geol. Soc.*, vol. xii, p. 136, and vol. xv, p. 215; *Proc. Geol. Assoc.*, vol. ii, p. 170, in which Caleb Evans mentions similar gravels at St. Helens, King's Quay, and E. of Ryde.

** An interesting comparison suggests itself between these deposits and those of the Lower Thames Valley.

†† "The Pleistocene Deposits of the Sussex Coast and their Equivalents in other Districts," *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 344.

‡‡ "On the Newer Tertiaries of the Sussex Coast," *Quart. Journ. Geol. Soc.*, vol. xiii, p. 40, etc.; see also "A Fossiliferous Pleistocene Deposit at Stone, on the Hampshire Coast," by C. Reid, *Quart. Journ. Geol. Soc.*, vol. xlix, p. 325.

Dorchester, and about 60 ft. above the present river, occurs a patch of sand with gravel seams, differing in many respects from those of the Bagshot strata found in that district. Mr. C. Reid classes it with the Bagshot, and considers it to be of the same age as the gravel at Hardy's Monument, 777 ft. O.D. Overlying the sand is a gravel deposit made up of flint, mostly subangular, a few Tertiary pebbles, some 2 in. but mostly small, small pieces of schorl-rock, Purbeck marble, and quartz up to 2 in. It rests unevenly upon the sands, apparently in a channel, is covered by a brick-earth in one part, and appears to be a low-lying drift deposit of Pleistocene age derived from the Bagshot gravels and the High Level Drift on Blackdown.

Prof. Prestwich* has recorded Mammoth and other remains from Portland, 400 ft.,† and Encombe Park, 240 ft., on the Isle of Purbeck. Drift gravels also occur on the hills above Portisham, near the Hellstone, about 600 ft. O.D., and at lower levels 300, 150, and 70 ft., near Weymouth, pointing to another valley system now almost entirely swept away.

It appears that the valley of the Frome has had a similar history to that of the Thames, allowance being made for greater denudation.

4. WEST DORSET AND DEVON.

(a) High Level or Early Drifts.

(i.) The drift at Hardy's Monument on the watershed already referred to.

(ii.) The drift on the Haldon Hills.‡ This is on the western side of the series of valleys now under consideration. It is over 800 ft. O.D., and while its composition, closely resembles that near Hardy's Monument (777 ft. O.D.), the Haldon deposit differs in some respects. It appears to have been deposited by separate streams draining neighbouring areas of Dartmoor, rather than by parts of the same stream. The two deposits are about 4½ miles apart. Judging from the slope and the nature of the materials, the Haldon gravels would appear to have been deposited by a stream flowing south, and those on Hardy's Monument by one flowing west. Good sections are to be seen on Great Haldon, near the Race Course, about 7 miles from Exeter, where there are extensive workings on the upper

* "The Raised Beaches and Head or Rubble Drift in the South of England, their relation to the valley drifts, etc." Prof. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 403.

† "Notes on the phenomena of the Quaternary Period in the Isle of Portland," *Quart. Journ. Geol. Soc.*, vol. xxxi, p. 20, etc.; see also *The Dorset Natural History and Antiquarian Club Reports*, vol. xvi, p. 70.

‡ *Geol. Mag.*, vol. iv, p. 300 et seq.; "Railway Geology from Exeter to Newton Bushell and Merton Hampstead," by D. Mackintosh; see also "Eocene Beds of Devon and Dorset," by C. Reid, *Trans. Geol. Soc.*, vol. liv, p. 71.

slopes and summit of the ridge. The gravel consists chiefly of flint up to 2 by 1 in., some angular, some partially or completely rounded. No Tertiary pebbles or jasper were seen, but numerous blocks of granite, up to 12 by 6 in., containing much schorl; pieces of dark schorl-rock, up to 9 by 6 in.; quartz, up to 6 by 3 in., and many other kinds of rock. The larger transported blocks came from the top pits, in the lower pits they were fewer and smaller.

On Little Haldon, 5 miles south of the preceding sections, the gravel is about 6 ft. deep in the pits examined; blocks and fragments of angular flint, up to 24 by 12 by 3 in., made up the greater portion. I saw no Tertiary flint pebbles, or chert, but there was plenty of quartz up to $2\frac{1}{2}$ in. Some of the flints were partly rolled. Numerous pebbles of granite, up to 5 by 4 by 3 in., and schorl-rock, up to 5 by 4 in., were seen, and one fairly large piece of jasper. In one pit, near the base, a patch of white pipe clay was seen, and sandy patches occurred in the gravel.

(iii.) The Blackdowns are capped by a chert drift containing small pieces of quartz lying on the Greensand. A section at the top near the Wellington Monument, 892 ft. O.D., and Hemyock showed 2 to 3 ft. of chert drift in an earthy matrix.*

(b) Lower Level Plateau Gravels.

(i.) Between the valleys of the Brit and the Axe, on the hills between Charmouth and Axminster, and near Lyme Regis, is a drift at about 500 ft. O.D., consisting of chert and flint in an ochreous clayey matrix. Sections can be seen near the tunnel at the top of the hill, through which the road from Charmouth to Axminster is made. In places the gravel was very irregularly deposited, and contained dark greenish, sandy, clay patches. Other sections occur nearer Axminster, in one of which, blocks 2 by 1 ft. were observed. Its position on the watershed of two recent valleys, and opposite the Chard Gap, its composition and its height, 500 ft. O.D., all seem to point to its being a Lower Plateau gravel, which formerly may have extended much further south, since it caps the hills on the sea-shore.

On the slopes of Shute Hill (567 ft. O.D.) above Kilminster on the right bank of the Exe, similar flint and chert drift in a clayey matrix was observed.

(ii.) On the high ground west of the Otter above Fairmile, 388 ft. O.D. near Sidmouth Junction, a drift occurs, full of erratics, derived probably from New Red Sandstone Conglomerate, and further south, at the top of the hill between Exmouth and Budleigh Salterton, is a large deposit of drift material 20 ft. thick containing an abundance of red quartzite pebbles, and blocks

* For other gravel deposits see "The Drift of Cornwall and Devon, its Origin, etc.," by T. Belt, *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 80; "Notes on the Geology of the Valley of the Upper part of the Teign and its Feeders," by G. W. Ormerod, *Quart. Journ. Geol. Soc.*, vol. xxiii, p. 423.

up to 12 in. long. Quartz pebbles are plentiful, but I saw no flint.

(iii.) On the western side of the Exe, at Woolborough Hill,* south of Newton Abbot and Milber Down, is a drift derived, in part, from the Haldons. Pieces of rolled schorl-rock and small quartz occur, also large flints which are more rounded than those on the Haldons.

The drift between Charmouth and Axminster is directly south of the gap at Chard, and is made up of the sweepings of the upper Plateau drift on the Greensand at Blackdown. The drifts on the east side of the Exe are also directly opposite open communication to the north *viâ* the Culm Valley, and the low pass west of the Blackdowns. The position of these deposits, therefore, seems to have been determined by a strong current or stream from the North. The Woolborough gravels appear to denote a similar stage in the history of the Teign Valley, which has been formed between the Haldons and Dartmoor, since the deposition of the High-level drift upon them.†

(3) River Deposits.

(i.) The valley of the Exe above Chard Junction is comparatively free from drift, containing even local material. From this point however, and at levels of about 150 ft. O.D. much drift gravel is found. At Broom Ballast Pit it is very extensive, and over 30 ft. thick, and is made up of the *débris* of the High and Lower Level Plateau drifts, such as chert, flint, quartz, and schorl-rock pebbles. It is regularly stratified in places, has sandy or clayey partings here and there, and is covered by patches of a brick-earth deposit. Roughly shaped chert implements are abundant, *mostly in the bottom layers*.

At Chard Junction Station, G.W.R., is an old section of a similar gravel. Nearer Axminster a deposit occurs, containing worked flints. Twelve feet of this gravel was being worked, but there is more below. Near the top were some sandy layers. On the opposite side of the Axe valley at Kilminster, it again occurs and is well seen in a roadside section, 16 ft. deep, having patches of sand in places. Rudely chipped cherts also occur here, large blocks of chert up to 10 × 8 in. schorl-rock, etc. Another section occurs near Colyton Station at 100 ft. O.D.

In the lower part of the Otter Valley at Fairmile, 164 ft. O.D., at the back of an inn, is a fine section in a drift derived presumably from the New Red Sandstone Conglomerates. It is about 30 ft. deep, and contains a very varied assemblage of rocks. Quartz and quartzite are plentiful, also pebbles of a dark kind of rock. The boulders vary in size up to 2 ft. long.

* Cf. "Notes on the gravels, sands and other superficial deposits in the neighbourhood of Newton Abbot, Devonshire" by H. B. Woodward, *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 230.

† For further interesting remarks on this district, see "On the Bovey deposit," by J. H. Key, *Quart. Journ. Geol. Soc.*, vol. xviii, p. 9.

Lower down the same valley, about half a mile from Budleigh towards Salterton, on the right of the road, is a similar gravel to that at Fairmile, 184 ft. Q.D. It is about 8 ft. deep, with quartzites to 12×9 in.; black veined stones, quartz, chert, flint, etc. In the Culm Valley close to Tiverton Junction Station is a very similar deposit.* Mr. Godwin Austen states† that remains of *Elephas*, etc., are found in the valleys leading out from Charmouth Bay and from the Exe and the Brit.‡

Between Kingskerswell and Newton Abbot, at lower levels than the gravels on Woolborough Hill, are extensive deposits of gravel (in one place 45 ft. deep) derived from the higher drifts, etc.

At Bovey Heathfield, overlying the pipe-clay deposit containing beds of lignite, a gravel 6—8 ft. deep occurs, of a rather more complex character than that at the Haldons. Quartz fragments up to $3\frac{1}{2}$ in. were seen, and numerous granite pebbles up to 5 in. long, together with many pieces of schorl-rock, but no flint.§

The three stages observed in the Frome Valley are present in this series of valleys, and the greater thickness of the River Drift gravels tells of greater denudation as we proceed westward.

WEST DEVON AND CORNWALL.

Further west the character of the country changes entirely. Evidence of glacial action,|| more or less reliable, has been cited by various authors, and deposits of gravel have been noticed up to 900 ft., O.D. I saw very little drift to the south between Newton Abbot and Plymouth. At Brent Tor, on the western side, blocks of jasper were formerly plentiful, but on the occasion of my visit, I could only find fragments built into garden walls. This fact is mentioned owing to the presence of rolled pebbles of that substance further east. The Tamar flows at low levels, dividing the high ground around Dartmoor from that around the Bodmin moors. It is possible to cross the country here along the valley of the Tamar and the Bude Canal without rising more than about 322 ft. O.D. This would lead us to suspect that, formerly, a stream drained the west of Dartmoor, and to this stream is probably due the quartz gravel described as occurring at the Hoe, Plymouth,¶ and at Cattedown, 60 to 70 ft. O.D.**

* Cf. *Trans. Devon Assoc.*, vol. xv, p. 346.

† *Op. cit.*

‡ See also "The Chronological value of the Pleistocene Deposits of Devon," by W. Ussher, *Quart. Journ. Geol. Soc.*, 1877.

§ For section see *Quart. Journ. Geol. Soc.*, vol. xviii, p. 9.

|| "Glaciation in Devon and its Borders," J. B. Jukes, *Geol. Mag.*, vol. ii, p. 473; *Trans. Devon Assoc.*, vol. ix, pp. 177, 230. See also vol. viii, p. 48, *et seq.*, and vol. xii, pp. 301-311.

¶ *Trans. Royal Geol. Soc. of Cornwall*, vol. xi, p. 151. "Some detrital deposits associated with the Plymouth Limestone," by R. N. Worth; and *Trans. Devon Assoc.*, vol. xxi, p. 97, and vol. vii, p. 250.

** "Evidence of Glacial Action in Cornwall," by N. Whitley, *Trans. Royal Geol. Soc. of Cornwall*, vol. x, p. 132; "The Post Tertiary Geology of Cornwall," by W. Ussher, 1879; "Glacial conditions in Devon," by R. N. Worth, *Trans. Devon Assoc.*, vol. xiii, p. 351.

The deeply cut valleys running down from the Bodmin moors point to greater denudation than can be seen east of Dartmoor, and the almost total absence of high level gravels in Cornwall is to be accounted for in the same way. The agents of denudation seem to have acted on the country to such an extent that any such drifts must have been carried down to the valleys, or even to the sea, giving rise to quite a different series of deposits known as Raised Beaches, followed by a "Head" of local materials. That High Level Drifts were once present is shown by the fact that two or three deposits remain. On the slopes of St. Agnes' Beacon, at 300 ft. O.D., are to be seen 8 ft. of loam with angular blocks, and near it is a sand-pit 6 ft. deep, with quartz-sand and angular pieces of quartz.

On the Crouza Downs in the Lizard District, near Lanarth, close to the road running north to Helstone from Coverack Cove, at 360 ft. O.D., is an extensive deposit of quartz gravel 8 ft. to 10 ft. thick. There are several extensive old pits now filled with water, but only one was in use. The contents were mainly quartz fragments in an ochreous, sandy matrix. Covering the gravel, and in channels cut through it, was a more argillaceous deposit without gravel.* A flint and quartz drift also occurs on the Scilly Islands.†

The more acute denudation which has become apparent the further we have gone west, now requires explanation. At the present time, owing to the prevailing winds from the S.W. being laden with moisture, the rainfall increases towards the west. It would therefore be expected that if similar conditions existed in Cornwall during Glacial times we should have greater denudation. The scouring action brought about by the constant formation and melting of ice would be greatly intensified in such a district as Cornwall. The heights of the deposits at St. Agnes and Crouza Downs show that the gradual upward tendency on the east of Dartmoor is not maintained to the west of it, but rather indicate a slope in the opposite direction.

The order of deposition seems to have been as follows :—

- (a) High Level Drifts, *e.g.*, Crouza Down.
- (b) Formation of so-called Raised Beaches arising from the destruction of the High Level deposits.
- (c) Formation of the "Head," the conditions becoming so acute that when all the superficial deposits had gone, the solid rock was broken up and carried down.
- (d) Deposition of Stream-Tin Gravels containing remains of mammals.‡

* W. Tyack, *Trans. Royal Geol. Soc. Cornwall*, vol. ix, p. 177.

† *Trans. Royal Geol. Soc. Cornwall*, vol. vii, p. 343, "On the Chalk flints and Green sand fragments found on the Castle Down, Tresco, one of the Islands of Scilly."

‡ *Trans. Royal Geol. Soc. Cornwall*, vol. iv, pp. 55, 395.

In (a) we still have the representative of the High Level Plateau Drifts further east.

In (b) and (c) possibly the two stages noticed in the Lower Plateau or Glacial gravels, while (c) corresponds to the River Drifts.

The Westleton Drift.

Indications of streams flowing east and south from Dartmoor in Pliocene or earlier times have been shown to exist, but nothing has been said about streams flowing in a northerly or north-easterly direction during that period. In all probability, as stated in dealing with the valley systems of the South of England, high ground once existed from Dartmoor to what is now the Norfolk coast. The gaps which at present exist were then either absent or trivial, as shown by the altitudes of the various gravel beds deposited around them at subsequent periods. The chief gaps occurring W. of Goring Gap, are :

(1) The Avon Gap, near Etchelhampton Hill, is 364 ft. O.D., with associated gravels to the S. of it over 400 ft. O.D.

(2) The Stour and Cale Gap, 178 ft. O.D. Judging from the character of the strata, the absence of gravels, and the height at which mammalian remains occur at Blandford, this gap may be considered to be of recent date. The absence of the hard Chalk has led to rapid denudation.

(3) Chard Gap, 300 ft. O.D., with associated drifts to the S. 500 ft. O.D.

(4) The Culm and Spratford Stream Gap, W. of the Blackdowns, 400 ft. O.D., with associated drifts to the S. 500 ft. O.D.

It is quite possible that a river system draining this high ground existed, in other words, a peneplain was probably formed in a S.W. to N.E. direction. Such a stream from its southern tributaries would receive, among others, the following materials, which would go to make up its gravel deposits further east :

(1) Quartz pebbles of various kinds, as found on the Haldons and at Hardy's Monument ; (2) jasper ; (3) schorl rock at Hardy's Monument ; (4) rolled and subangular pieces of chert from the Greensand hills of Dorset and Devon which supplied the Blackdowns, etc. ; (5) red quartzite pebbles from the uppermost beds of the New Red Sandstone Conglomerates, (6) *débris* from rocks in West Devon, such as radiolarian chert, pebbles with crinoid stems, etc., etc. ; (7) *débris* from Tertiary strata encountered further east.

Now these actually do occur in the Westleton Drift, and can be traced right away to the Norfolk Coast, as previously shown.*

In the Thames Basin these materials are found in a drift

* *Op. cit.*

which has in all probability come through the gaps in the Chalk range. It has, in fact, been *re-drifted* at a subsequent period.

Mr. Osborne White, in a recent communication to this Association,* was able to follow Prof. Davis' theory in all but one point. The Professor required for the full development of his theory a peneplain, such as I have above indicated. The Westleton Drift is not necessarily of marine origin, as I have previously pointed out.† Its contents, its position and its age show it to be but the re-drifted deposits of a stream running across Central England in Pliocene or earlier times. As far as I know at present, no undisturbed deposits of the actual stream have been found. They have all apparently disappeared during the periods of acute denudation which followed.

In conclusion I beg to thank the writers of the numerous papers quoted, to acknowledge my indebtedness to the recently published Index to vols. 1—50 of the *Quarterly Journal of the Geological Society*, and to the contoured maps issued by the Ordnance Survey.

* *Op. cit.*

† *Op. cit.*

ORDINARY MEETING.

FRIDAY, 4TH MARCH, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

Mr. A. E. Salter, B.Sc., F.G.S., read a paper, entitled "Pebbly and other Gravels of Southern England," illustrated by numerous specimens, maps, and sections.

A series of photographs presented by Mr. Thomas Parker, C.E., F.G.S., of Rockhampton, Queensland, were exhibited showing the workings at the Mount Morgan Gold Mine, Queensland.

ORDINARY MEETING.

FRIDAY, 1ST APRIL, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

Prof. A. M. Edwards, M.D., H. Stanley Jevons, B.Sc., Charles St. Arnaud Coles, and Miss Margaret I. Gardiner were elected Members of the Association.

Addresses dealing with the Excursion Programme for 1898 were delivered by H. W. Monckton, F.L.S., F.G.S., the Rev. Prof. J. F. Blake, M.A., F.G.S., Aubrey Strahan, M.A., F.G.S., and W. Whitaker, F.R.S., Pres. G.S., their remarks being illustrated by maps and sections.

VISIT TO THE MUSEUM OF PRACTICAL GEOLOGY JERMYN STREET.

SATURDAY, MARCH 5TH, 1898.

Directors : THE PRESIDENT, F. W. RUDLER, AND
E. T. NEWTON, F.R.S.

(*Report by the* DIRECTORS.)

THE members, to the number of more than fifty, assembled in the Lecture Theatre at three p.m., and were received by the President, who made a few introductory remarks.

Mr. Rudler briefly described the arrangement of the objects in the Hall, and in the principal gallery of the Museum. The Hall is primarily devoted to the exhibition of specimens illustrating the application of the rocks of the British Islands to purposes of construction and decoration. The constructive materials are represented by several hundred six-inch cubes of limestone, sandstone, and other building stones, many of which were collected by the Royal Commission appointed in 1838, to select the stone to be used in the erection of the new Houses of Parliament. The ornamental stones of this country are represented by a large series of polished cubes, and also by numerous columns, vases, and other decorative objects. Most of the granites, marbles, serpentines, and alabasters of Britain receive effective illustration in this department.

There will also be found in the Hall examples of various rocks which are employed architecturally in consequence of their fissility ; this series includes not only cleaved rocks, like slate, but such laminated rocks as can be split up for use as roofing-tiles, paving-slabs, etc.

In the table-cases on the western side of the Hall, are specimens illustrative of the manufacture of the principal varieties of cement and plaster, as also a series of abrasive materials, with examples of millstones, grindstones, scythe-stones, hone-stones, etc.

It was originally intended that all the Mineral Collections should be exhibited on the Principal Floor of the Museum, but the important bequest by Mr. Henry Ludlam, received in 1880, rendered it necessary to modify this intention. The Ludlam Collection of Minerals, which could not be accommodated upstairs, is placed mostly in the Hall. Here, too, are necessarily arranged such massive and heavy objects, as could not find appropriate display elsewhere. Quite lately, for example, there has been added to the assemblage of miscellaneous objects in the Hall, a large slab of limestone from the Yoredale beds at Barton, in North Yorkshire, displaying a well-marked glaciated surface.

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In accordance with the practical character of the Institution the Mineral Collections, exhibited on the chief floor, are arranged on such principles as to be of service to the miner and to the general visitor without scientific training. The primary division is into a metalliferous group, and a so-called non-metallic group of minerals.

The metalliferous minerals, or Ores, are arranged in a series of wall-cases—the British ores being separated from the foreign ores, and these again from the Colonial products. The minerals from the Colonies are classified geographically, since a visitor not unfrequently desires to study the mineral products of a certain British Possession. In the other collections of ores, the minerals of each metal are kept together; thus, all the copper ores of Britain will be found in a compact group, collected in a series of adjacent cases. In front of the British copper ores will be found a table-case with specimens illustrating the dressing and smelting of such ores. The mineral collection is thus supplemented by a metallurgical collection. Finally, the metal having been extracted from its ore, an attempt is made to show how this metal is utilised in the arts; and thus it comes about that a case is devoted to statuettes, vases, etc., cast in copper and its various alloys. The collection is, therefore, essentially technological, comprising examples of the ores, the metals, and their industrial applications.

The so-called “non-metallic minerals” are displayed in the large series of desk-cases in the central area of the Principal Floor, known as the Horse-shoe Case. Here are found not only minerals which are strictly destitute of any metal—such as the natural forms of carbon, sulphur, and silica—but also a great number of spars, precious stones, and earthy minerals which, notwithstanding their popular designation as “non-metallic,” contain various metallic elements, but generally the lighter and rarer metals. A characteristic feature, here as elsewhere, is the attempt to show the economic uses of each mineral.

Illustrations of the utilisation of clays in the manufacture of pottery, and of sands in the production of glass, led, in the early days of the Museum, to the formation of ceramic and vitreous collections. These collections, which have acquired considerable importance, are, however, kept together as a special department of the Museum.

Mr. E. T. Newton followed with an account of the fossils exhibited in the galleries. The specimens are arranged in such a way as to illustrate most admirably the various formations shown on the Geological Survey maps. The collection, which has grown during many years, includes several important series of fossils brought together by private workers, and contains a great number of type specimens. The speaker called attention to certain of the more striking and interesting specimens, among which he mentioned: a portion of a hollow stem of *Lepidodendron*,

from the Carboniferous rocks of Midlothian, which has been filled in with volcanic *débris*, but still has some of the woody structures most beautifully preserved; a unique example of the antler of *Cervus verticornis*, from the Norfolk Forest Bed; the wonderful horned and other reptiles from the Elgin sandstone; the elephant remains described by Dr. Hicks from near Euston Square, and lastly, the fossil human remains from Galley Hill, Northfleet; probably the best authenticated specimen of Palæolithic man yet found.

The President then gave a brief account of the arrangements of specimens in the Rock-room (see PROCEEDINGS, vol. xii, p. 322, and vol. xiv, p. 97), and concluded by expressing the thanks of the Association to Mr. Rudler and Mr. E. T. Newton for their excellent addresses.

VISIT TO THE SOUTH KENSINGTON MUSEUM, SCIENCE DIVISION.

SATURDAY, MARCH 26TH, 1898.

Director: PROFESSOR J. W. JUDD, C.B., LL.D., F.R.S.

(*Report by H. W. MONCKTON, with corrections and additions by the DIRECTOR.*)

THE members of the Association were received by the Director in the vestibule of the western galleries at 3 p.m. After a few words of welcome, the Director led the way into the gallery, drawing attention, at the entrance, to some old maps of London which illustrate the gradual growth of our city, and show how much the direction of its extension has been influenced by geological features. It would be impossible within the confines of this report even to mention the numerous objects of interest having a bearing on geology to which the Director drew attention, nor is it necessary to do so, for the gallery is open to the public and the exhibits are most carefully and clearly labelled; but a few may be mentioned as having more particularly attracted the attention of the members of the party.

General Colby's "compensation bar," a most ingenious arrangement of brass and iron, was used in 1827-8 in the measurement of base lines on Salisbury Plain and near Lough Foyle, for the Ordnance Survey of the British Isles, and is of interest to the geologist since the value of a geological map depends to no inconsiderable extent on the perfection of the topographical survey of the area in question. The zenith-sector, and the great theodolite used in the Ordnance Survey attracted attention, as did also the very compact piece of apparatus used by Prof. Boys in determining the constant of gravitation, and thus weighing the earth.

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The Director then drew attention to a beautiful series of sketches in chalk of the wonderful sunset effects which followed the great eruption of Krakatoa in August, 1883, supposed to have been due to the vast quantities of excessively fine volcanic dust thrown into the air during the eruption. These drawings were all made in the neighbourhood of London, by Mr. W. Ascroft. They are mounted on revolving frames, and some time was spent in their inspection by the members.

On entering the second gallery the course of the tour of inspection was interrupted by a small geyser which suddenly came very actively into operation. During one of its passive periods the Director explained its construction, which is beautifully simple, simpler even than the model designed by Prof. J. Müller, of Freiburg, which required two fires, whereas the one inspected needed only one. The Director said that the violence of the eruption could be greatly increased by a diminution in the aperture of the tube, but there was a general feeling that the eruption was sufficiently formidable. A beautiful working apparatus, constructed by Mr. Clayden, showed the ocean currents of the world, and the effect on the Gulf Stream of the removal of Central America was illustrated. Another working model, designed by Mr. C. J. Woodward, of Birmingham, illustrated the formation and manner of growth of a volcanic cone in a simple and ingenious manner.

A large number of pieces of apparatus made expressly for geological or mineralogical investigation were shown, and examined with critical interest by members whose tastes lay in various special directions. Specific-gravity balances had a fascination for some; petrological microscopes and machines for cutting rock-sections for others, and several beautiful series of models to illustrate the principles of crystallography attracted the attention of all.

A very instructive series of geological maps, containing representative examples of the publications of the various European, American, and Colonial Geological-Surveys with early geological maps of historical interest, and some geological models, next engaged the attention of the members. After an inspection, all too hurried, of these and many other exhibits, the party passed on to a lecture-room, where Professor Judd gave a short address on

GEOLOGICAL MAPS: THEIR ORIGIN AND DEVELOPMENT.

The collection of geological maps exhibited in the galleries of the Museum enables the geologist to contrast the various excellences and defects which such maps may display. Some of these maps are distinguished by the fidelity with which they illustrate the geological structure of a district; others are noteworthy for the beauty, transparency, and harmony of their colouring, being truly artistic as well as scientific productions; while others again,

and this is a matter of no little importance, are remarkable for the methods of reproduction adopted, which enable them to be sold at an extremely cheap rate.

It is of great interest to the geologist to study the various steps by which the art of geological mapping has arrived at its present state of development. For this reason a historical series of geological maps has been arranged in the galleries. The whole question of the origin of geological maps has been treated with great learning and research by Dr. W. H. Fitton, in an article first published in the *Edinburgh Review* in 1818, and afterwards issued in more extended form in the *Philosophical Magazine* for 1832-3. Although some of Dr. Fitton's conclusions have been challenged by more recent authors, a careful study of the facts affords the strongest proof of the sound judgment and perfect impartiality of that distinguished geologist.

In the history of scientific discovery, much more importance attaches to those enunciations of truth which have been placed before the world in such a way as to influence scientific progress and produce real results, than to the remarkable (but often dim) fore-shadowings of the same truth that may have preceded the *effective* discovery by some years, but have borne no fruit whatever.

Three very distinct stages in the development of the art of geological mapping may be very clearly recognised, and these will always be associated with the names of Lister, Werner, and Smith respectively.

The first maps of the kind could not be called "geological" maps at all in the proper sense of the term—they were simply mineral or agricultural (soil) maps. It is impossible to say when such maps were first constructed. To many persons, in distant places, it must have occurred to indicate upon the surface of a map, the distribution of minerals and soils. To construct such a map, indeed, would require nothing but the most ordinary industry and perseverance. But there can be no doubt that a paper by the "learned Dr. Martin Lister," published in the *Philosophical Transactions* for 1684, had a most important influence in pointing out the value and uses of such maps, and in quickening research in that direction.

Maps which could be properly called "geological" were first produced when the fact came to be clearly recognised that the rocks seen at the surface are the "basset edges" or "outcrops" of strata, and that these strata have an invariable order of succession. Now although Werner was anticipated in this discovery by Steno in Italy (1669), by Strachey (1719-1725) and Michell (1760) in this country, and by Lehmann (1756) and Fuchsel (1762) in Germany, yet it is certainly due to the efforts of the great Saxon mineralogist, at the end of the last century, that geological maps began to be extensively made. Werner's pupils, fired with his enthusiasm and informed with his exact mineralogical

but narrow teachings of their great master. It has been pointed out by M. Jules Marcou that Smith's great discovery has been adumbrated by the Abbé Giraud-Soulavie, as early as 1777. The work of Giraud-Soulavie was absolutely unknown to William Smith, and even to Cuvier and Brongniart, who first applied the principles of William Smith to the investigation of the Paris Basin. The documents in the possession of the Geological Society, which facsimiles are exhibited in the Science Museum, prove that Smith had completed his geological map of the neighbourhood of Bath in 1799 and his first sketch of his geological map of England and Wales in 1801, while Cuvier and Brongniart did not commence their geological investigation of the Environs of Paris till 1808 and their map did not appear until 1810.

Smith's great geological map of England and Wales was published in 1815; Macculloch's geological map of Scotland in 1835; and Griffith's geological map of Ireland in 1838. The first complete geological map of France, that of Elie de Beaumont and Dufrenoy appeared in 1840.

At the conclusion of the lecture, the President proposed a vote of thanks to the lecturer. He said that he had listened with the greatest interest to the account of the various steps by which the art of geological mapping had been gradually advanced to its present perfection. He complimented the Director on the manner in which the exhibits had been collected together and arranged in the galleries, and said he was certain the members had never seen a collection of apparatus such as was not to be found in any other place. It had been made, he ventured to think, with common-sense and ordinary judgment, and was admirably adapted for the purpose of teaching geology.

A vote of thanks was carried by acclamation, and the members were subsequently most hospitably entertained at tea by the President.

EXCURSION TO BRIDPORT AND WEYMOUTH.

EASTER, 1898.

Directors: J. F. BLAKE, M.A., F.G.S.; W. H. HUDLESTON, M.A., F.R.S.; AND S. S. BUCKMAN, F.G.S.

Excursion Secretary: E. P. RIDLEY, F.G.S.

(*Report by the DIRECTORS and H. W. MONCKTON.*)

THE official party left Paddington Station (G.W.R.) at 3.15 p.m. on Thursday, April 7th, and on arrival at Bridport proceeded to the Bull Hotel, where it was joined by many members who had travelled by other trains or from different parts of the country.

The principal features of the excursion were intended to be (1) the comparison of the development of the Inferior Oolite in the south of Dorset with that examined last year in the Cheltenham district; (2) the investigation of the general succession of the Jurassic series from the Inferior Oolite to the Portlandian, and (3) the demonstration of the remarkable stratigraphy of the district, showing faulting and folding at different epochs.

In pursuance of the first object the Association had the advantage of the guidance of Mr. S. S. Buckman, who had acted as Director in the Cheltenham area, and whose views will be found in the following Report. The result seemed to be expressible somewhat in this way, that whereas at Cheltenham we saw an abundant development of the middle portion of the series and little of the lower and upper parts, in Dorsetshire there was scarcely any of the middle division, but a fair representative of the remainder.

Friday, April 8th.—The party drove from Bridport to Seaton, a small village on the coast about three miles west of Bridport. Leaving the carriages, the members walked to the top of Down Cliff where Mr. Buckman delivered a short address on the geology of the district (see Fig. 1).

The rocks belonged, he said, to the Jurassic series, capped unconformably by Cretaceous. At Chideock Hill to the north, which had been passed on the drive from Bridport, there was a small outlier with a hard capping of Inferior Oolite. The valleys around had been cut down to the Lower Lias. Last Whitsuntide the Association, when at Cheltenham, was, unfortunately, unable to see the Cephalopoda Bed, which, in that area, is the representative of a considerable thickness of the strata at Chideock Hill.

Mr. Buckman pointed out the position of the junction bed of the Upper and Middle Lias. A few inches of the strata are cemented to the Marlstone, and about eighteen inches from the Marlstone *Ammonites striatulus* is found in the junction bed.

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The Marlstone contains *A. spinatus*. This junction bed above the Marlstone is represented by some 300 feet of strata in the Cotteswolds.

The Geological Survey Map is not consistent on this point, for the clay above the place where *A. striatulus* is found is here mapped as Upper Lias (g^3); but in the Cotteswolds the strata with *A. striatulus* and some 250 feet below that are mapped as Midford Sand (g^4). So that the map has really reversed the true

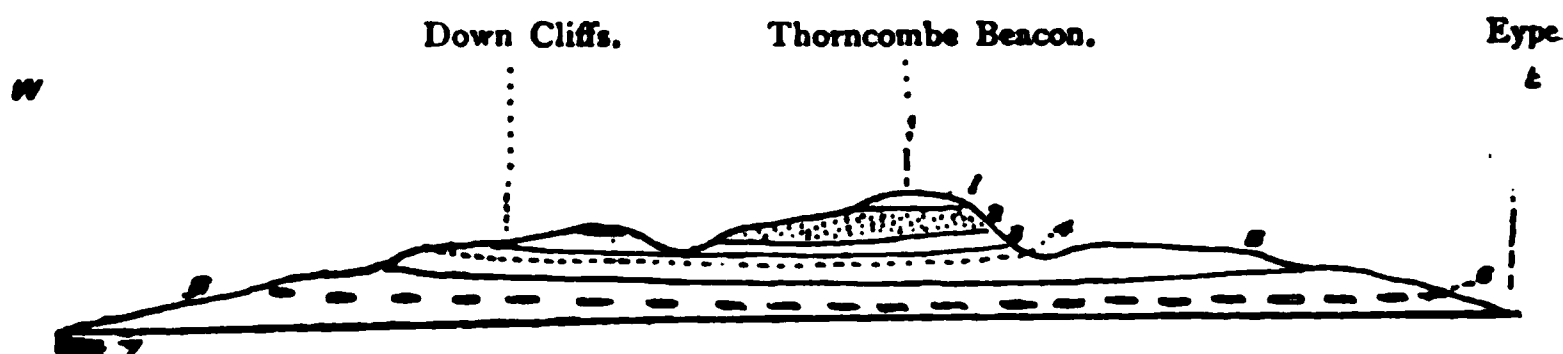


FIG. 1.—SECTION ALONG THE COAST OF DORSET, WEST OF EYPE-MOUTH.—
H. B. Woodward.

- | | | |
|---------------------------------------|--|--|
| 1. Upper Greensand. | 4-7. Middle Lias--zones of <i>Am. margaritatus</i> and <i>A. spinatus</i> . | 5. Yellow sands with "doggers." |
| 2. Bridport Sands. | 4. Sandy Limestone, overlain by clays and Junction-bed of Middle and Upper Lias. | 6. Laminated sand and clays with Starfish Bed. |
| 3. Upper Lias—clays and sandy shales. | | 7. "The Three Tiers" |

Figs. 1, 3, 4, and 5, are reproduced by the kind permission of the Director-General of the Geological Survey.

order of the strata in the two places, and has made the pre-*striatulus* beds of later date than the post-*striatulan* rocks.

Pointing to the cliff section at Thorncombe Beacon, which was in view of the members, Mr. Buckman said that the 70 feet of blue clay seen was the bed he alluded to mapped as Lias here. Below it was a well-marked line in the cliffs. That was the junction bed, about 2 feet thick. The strata of that band were in four layers, viz. :

1. Bed with *A. striatulus*.
2. Bed iron-coated, remainder *A. bifrons*.
3. Bed with *A. falcifer*.
5. Bed with *A. spinatus*,

while Mr. Day spoke of a fifth layer—a *Pleurotomaria*-bed, which Mr. Buckman said he had never been able to find; but he knew that owing to contemporaneous erosion even the four parts are not found in every portion of the band.

On this section Prof. Blake remarks that it extends from the *Margaritatus*-clays to the Bridport Sands. Towards the middle the narrow band above mentioned is seen, making a feature in the cliff. Below this band were *Margaritatus*-sands, above it is clay; of this clay two correlations have been made. According

to the Geological Survey it is Upper Lias; according to Mr. S. S. Buckman they are of the same date as the Yeovil Sands of North Dorset, which the Survey, however, map as Midford Sands. Mr. Buckman particularly refused to have anything to do with the terms Upper Lias or Inferior Oolite. His point was that the clay was *Dumortieria*-beds, which are post-striatulan; that on the Dorset coast the *Dumortieria*-beds are called Upper Lias; in the Cotteswolds they and 250 feet below them are mapped as Midford Sands. One, he said, must be wrong.*

Evidence was accordingly sought to determine which of these two views most accurately represented the facts. Lithologically considered, nothing seemed simpler. There were the Middle Lias sand beds, capped by a hard band, with *A. spinatus*—the Marlstone, followed by dark clay—the Upper Lias, passing up into the Bridport Sands.

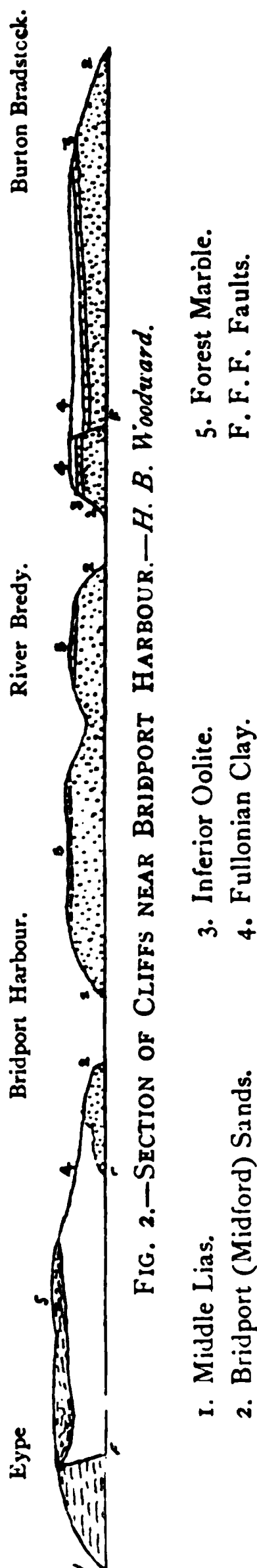
But the crux of the question lay in the narrow hard band referred to the Marlstone. According to Mr. Buckman this contained not only the zone of *A. spinatus*, but those of *A. falcifer*, *A. bifrons*, *A. striatulus*, and possibly a fifth. The members, therefore, eagerly sought this “quinquezonal” rock. It was almost inaccessible for a party, but blocks that had fallen down could be easily examined. Prof. Blake remarked that, strictly speaking, there were no zones in it at all. The fossils were not arranged in a regular or any order, but thrown miscellaneous together.

Mr. Buckman pointed out that the specimens were not lying horizontally; but though each layer might show that specimens were drifted together, yet, as the result of continuous work at the bed, he had found that the fauna of each layer was practically distinct; that *A. striatulus* occurred only in the top layer, and that therefore the overlying clays were younger than the *Striatulus*-beds. Amongst its fossils the members certainly found *A. spinatus*, Brug., *A. falcifer*, Sow., and *A. bifrons*, Brug., and possibly *A. striatulus*, Sow.

It was plain, Prof. Blake continued, that we had here to do with an *aggregate* deposit formed, as it were, by the sweepings of several zones elsewhere, and that the overlying clays were, at least, younger than the *Striatulus*-beds. Still, there is room in the usually accepted Lias for higher beds than those with *A. striatulus*, and in this way the inclusion therein of these clays might be justified. On the other hand, the occurrence of this curious aggregate rock indicates a break in the order of sequence, and suggests that the succeeding clays belong to a new series.

The approximate junction-line of the clays and overlying sands may, no doubt, be mapped by the aid of springs and

* [“Midford Sands” is used by the Geological Survey as a stratigraphical term to include the Gloucestershire Cephalopoda-Bed and Cotteswold Sands, and also the Midford, Bridport, and Yeovil Sands.—ED.]



similar surface indications ; but the passage seems a gradual one, and was not accessible to direct observation.

Prof. Blake then led the way eastwards along the shore to Eype, the next point of interest being the great fault which brings down Bathonian beds into juxtaposition with Middle Lias (see Fig. 2). This is one of a series running more or less in an east and west direction and connecting with those better known in the Weymouth anticlinal. The Bathonian beds here are distinguished as Fuller's Earth and Forest Marble, the line of junction being taken below a prominent bed full of *Rhynchonella boueti*. There is not much lithological distinction hereabouts, and the line of junction, Prof. Blake thought, was more or less palæontological and arbitrary. (See Fig. 3 ; also photograph in Brit. Assoc. Coll.)

At Bridport Harbour a halt was made for lunch. After the luncheon interval the party walked in an easterly direction towards Burton Bradstock, and visited a small quarry in the *Parkinsoni*-zone of the Inferior Oolite. A short halt was made here and a considerable number of fossils obtained, including :

Clypeus altus, M'Coy ; *Collyrites ovalis*, Leske ; *C. ringens*, Ag. ; *Holctypus hemisphæricus*, Desor. ; *Terebratula sphaeroidalis*, Sow. ; *T. stephani*, Dav. ; *Ammonites parkinsoni*, Sow.

The river Bredy was then crossed, and beneath Burton Bradstock Cliff the members had a good opportunity of observing the whole of the small thickness of rocks which go by the name of the Inferior Oolite Limestone. The underlying Bridport Sands were easily verified as belonging to the *Opalinus*-zone, in which is included also their limestone capping.

Above this is a very distinct, well separated band, with a base-line of curious nodules or ferruginous concretions, and portions of an ironshot matrix similar to that of the *Murchisonæ*-bed at Chideock Hill. Mr. Buckman calls it *Witchellia*-beds, and others have referred it to the *Murchisonæ* or *Humphriesianus*-zones.

After another break comes a more massive limestone in which *Parkinsonia* abound,

and one of the members obtained a good example of *Morphoceras*, so that the horizon is clearly fixed. It is *above* this limestone that the line between the Inferior Oolite and Bathonian is usually drawn. Here, however, the overlying clay seems to be very closely connected with it, and at the base contains many ammonites usually referred to *Oppelia subradiata*. It would seem, therefore, that stratigraphically a break occurs below the *Parkinsonia* limestone, and that this latter should rather be included in the Bathonian series—a view which on palæontological grounds has been advocated by Messrs. Wilson and Buckman, at Dundry, and is consonant with the German and some of the French classifications.

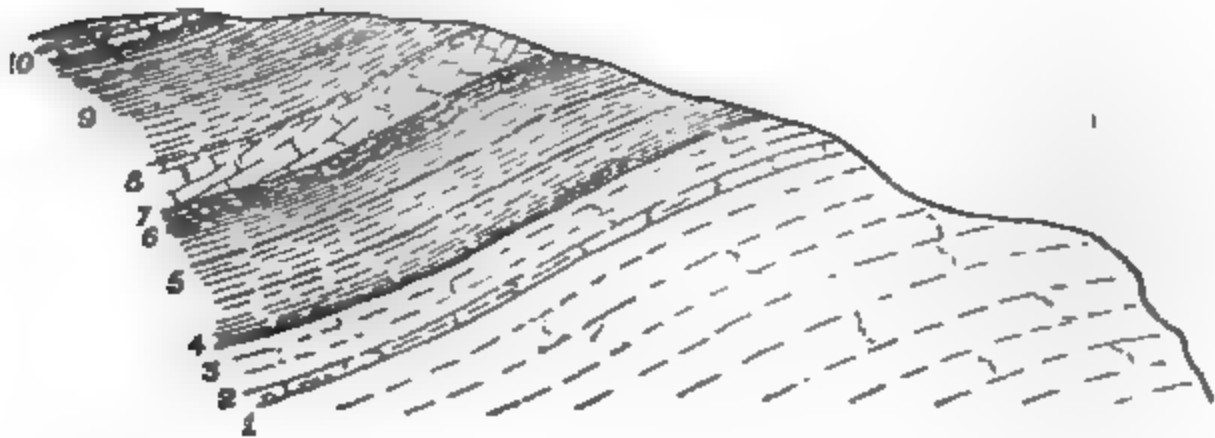


FIG. 3.—SECTION AT WEST CLIFF, BRIDPORT.—H. B. Woodward.

1—3. Fullonian Clay. 4—10. Forest Marble-clays with *Rhynchonella*-Bed (4) at base, and central mass of limestone (8).

Mr. Hudleston's reading of this part of the section will be found in the monograph on "The Gasteropoda of the Inferior Oolite" (Pal. Soc.), Part I, p. 31, and Mr. Buckman's reading in the paper on "The Cotteswold, Midford, and Yeovil Sands" (*Quart. Journ. Geol. Soc.*, vol. xlv (1889), p. 451).

On reaching Burton Bradstock, the party were met by carriages, and most of the members drove back to Bridport. A detachment, however, under the direction of Prof. Blake, left the carriages near North Hill, and visited several quarries in the Forest Marble on North Hill, and between it and the village of Bothenhampton. The section is published in H. B. Woodward's "Jurassic Rocks of Britain," vol. iv, p. 342. Fossils are very abundant, but it is not easy to obtain satisfactory specimens for the cabinet. After spending some time in the quarries, the detachment rejoined their carriage and drove to Bridport.

The Mayor of Bridport honoured the Association with his company at dinner, and, on behalf of the Mayoress, presented a box full of specimens of *Rhynchonella boueti* from the Forest Marble of the neighbourhood.

After dinner the President proposed votes of thanks to Mr. Buckman for assisting in the directorship during the day, and to the Mayor and Mayoress for the present of *Rhynchonella*. Both votes were passed by acclamation, and Mr. Buckman and the Mayor responded.

Saturday, April 9th.—Starting soon after 10 o'clock, under the directorship of Prof. Blake, the party drove by way of Swyre to Abbotsbury, and the Director remarked that those who had visited Bothenhampton on the previous evening, and all the party during the drive to Abbotsbury, were able to appreciate the very considerable amount of material which goes in this district to make up the "Fuller's Earth" and "Forest Marble." It is scarcely to be understood by the use of these terms that only those portions of the series which, in the neighbourhood of Bath, go by these names respectively are here represented, and that the Great Oolite and Bradford Clay are absent, but that lithologically these names are most suitable for the lower and upper portions of a continuous Bathonian series whose relations have as yet been inadequately worked out.

On reaching Abbotsbury new problems came up for solution. Descending the hill towards that village the members were able to satisfy themselves of the great pre-Cretaceous fault, bringing down the Abbotsbury ironstone almost on a line with the Forest Marble; and further to the east the same fault was confirmed, up Red Lane. With regard to the age of this fault, no section could be found in which the Cretaceous rocks were seen actually lying on the Jurassic; but the uniform level and irregular running of the outcrop of the former seemed to indicate that they do so, and are not faulted against them, as marked on *some* copies of the old Geological Map; and in this case it is obvious that the fault must have brought up the Forest Marble and allowed the overlying strata to be denuded before the Cretaceous rocks were deposited. Whether this pre-Cretaceous fault runs into the same line as the post-Cretaceous one that brings down the Chalk to a lower level than the Portland, at Portisham, or whether both are broken off and lost, could not be determined by any direct observations on the ground.

On the other side of Abbotsbury a very complete traverse from the Osmington Oolite of Linton Hill, through the *Trigonia*-beds, the Supra-coralline or Sandsfoot Castle beds, the ironstone, the Kimeridge Clay, the Portland and Purbeck beds of Portisham Hill was satisfactorily made. The Portland Limestone was found to be here not so fully developed as in the Island of Portland, but immediately over the flinty series—here containing *Ammonites giganteus*,—was seen a thin, dark, carbonaceous bed with fragments of wood. On this horizon two large trees were seen—one horizontal, some 6—8 ft. long, and hollowed out in the middle—the other vertical, with large spreading roots. Photographs

of these were taken, but the waning light has prevented them from being suitable for reproduction.* Above this the Purbeck series was continued to a band full of *Cyrena*.

Monday, April 11th.—Monday was devoted to an examination of the series downwards from the Oxford Clay to the Forest Marble, with Prof. Blake as Director. A few of the members crossed the Backwater to the opposite shore, and were able to pick up several ammonites of the *Cordatus* group—representing the upper part of the Oxfordian. The whole party walked along by the side of the railway to the other end of the section and searched the lower part containing *Cadoceras sublaeve*, reaching the Cornbrash at the end.

The rubbly character of this rock was noted, indicating that it is a basal deposit. Though no ammonites have been recorded from the Cornbrash in this locality, numerous examples of *Macrocephalites* were obtained, and one example which would probably be recorded as *A. discus*, but which is more likely to be the *A. Hochstetteri* of Oppel, recorded by him from the Cornbrash of Chippenham, though it has not yet been accorded a place in British lists. The Director drew attention to the fact that on the Continent the zone of *A. macrocephalus* was usually united with the Oxfordian, and that the indications here were that it ought to be so classed. For this purpose the variable character of the underlying Forest Marble in the district was recommended to be noted, and at a later part of the day it was shown to be argillaceous at Radipole, sandy and concretionary at the top of the

- FIG. 4.—SECTION N. AND S. THROUGH LINTON HILL AND ABBOTSBURY.—After A. Strahan.
1. Chalk.
 2. Upper Greensand.
 3. Gault.
 4. Forest Marble.
 5. Pre-Cretaceous fault.
 6. Kimmeridge Clay.
 7. Abbotsbury Ironstone.
 8. Sandsfoot Beds.
 9. *Trypania*-beds.
 10. Osmington Oolite.
 11. Lower Calcareous Grits.
 12. Oxford Clay.



* A photograph of this section may be seen in the British Association collection (1896 Dorset), now in the Library of the Jermyn Street Museum.—ED.

hill to the south, and shelly at Langton Herring, but it was always followed by the same kind of rubbly Cornbrash, everywhere recognisable by its *Avicula echinata*. This confirms the existence of a break below the Cornbrash, while the gradual intercalation of clays, and the similarity of the fauna indicate an absence of any break above it. The *Ornatus*-clays at Chickerel brickyards and the Brachiopod Beds at Herbyleigh provided the members with the desired collections of fossils, among which Mr. Newton named from the latter: *Rhynchonella boueti*, Dav., *Terebratula intermedia*, Sow., *T. maxillata*, Sow., *Waldheimia digona*, Sow., *W. obovata*, Sow., *Mytilus pectinatus*, Sow., and the very characteristic *Ter. coarctata*, Park.

After dinner the President proposed a vote of thanks to Prof. Blake and Mr. Hudleston for their kindness in consenting to act as Directors, and to Mr. E. P. Ridley for arranging the business details of the excursion. It was carried unanimously.

Tuesday, April 12th.—Directed by Prof. J. F. Blake and Mr. W. H. Hudleston, M.A., F.R.S., a party of about fifty left Weymouth at 9.30 a.m., and drove through Osmington to Upton, a small village about five miles north-east of Weymouth, situated in a fertile valley which runs in an east and west direction, with Chalk downs rising some 200 feet above it, both on the north and on the south. Leaving the carriages, the party ascended the southern slope of the south downs, and on reaching the top (about 500 ft.) Prof. Blake said a few words on the physical geology of the district, and pointed out the independence of the Cretaceous rocks to the underlying synclinal.

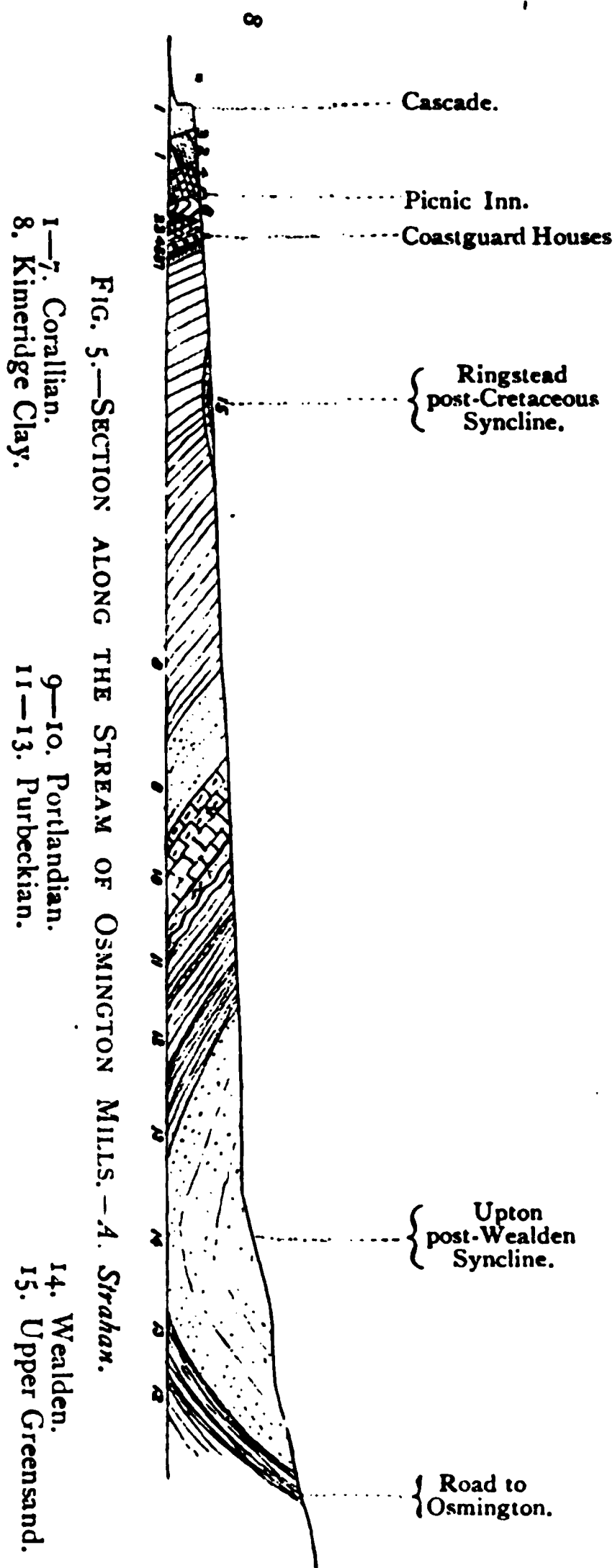
The party then descended on the seaward side of the down, and met Mr. and Mrs. Hudleston in the ravine above South Down Farm. Mr. Hudleston led the way to a road cutting showing the basal beds of the Upper Cretaceous, here including the Chloritic Marl, succeeded by the Lower Chalk, all dipping at a high angle towards the north. He took the opportunity of delivering a short address on the geology of the neighbourhood.

The district, he said, was one with stratigraphical peculiarities which are not exceeded in point of interest by any throughout the whole of England. On the hill slope above them was a bluff of Upper Greensand and Chloritic Marl overlain by Lower Chalk, all with a dip of about 70 deg. to the north. In the quarry below are to be seen Portlandian beds, which have a similar northerly dip. This high dip of the Cretaceous beds shows that the folding belongs to the system of post-Cretaceous disturbances. The disturbances so well marked in this district occurred at two distinct periods; the example before us belongs to the later of these periods, and is probably of Miocene age. Other disturbances would be seen in the course of the day, which can be proved to be of pre-Cretaceous age,

because they pass under the Cretaceous beds without affecting them.

The Cretaceous here belongs to the Upper Cretaceous down to the base of the Upper Greensand, with part of the Gault in places; and the Wealden would be treated as non-Cretaceous, because the Wealden here belongs to a different system of disturbance, and the Wealden of the synclinal passed over by the party this morning, folds with the Jurassics. (See Fig. 5.) As a matter of fact the Upper Cretaceous rests almost everywhere unconformably on the older rocks. This is remarkably the case on the western brow of the Yorkshire Wolds. There the Cretaceous rests on Corallian, Oxfordian, Lower Oolite, and Lias. Consequently there must have been a great physical change about the period during which the Cretaceous began to be laid down, and this holds true almost all over Europe, in Arabia, and probably also in India — one of the greatest overlaps we know of in the Old World.

At the conclusion of Mr. Hudleston's address the members proceeded to inspect the section, the high dip being very noticeable. The Lower Chalk here contains one or two imperfectly formed flints, but few fossils were seen, a fragment of *Ammonites navicularis*, Mant., in association with *Nautilus* being



found in the Chloritic Marl. The Upper Greensand contained an abundance of green grains and many fossils were found, amongst others *Exogyra columba*, Lam. ; *E. conica*, Sow. ; *Pecten orbicularis*, Sow. ; *Pecten quinquecostatus*, Sow. ; *Pecten* allied to *galliennei*, D'Orb. ; *Arca*, sp. ; *Cyprina*, sp.

Mr. Hudleston remarked that the high dip here seen only extends for a short distance from the line of disturbance, after which the beds became nearly horizontal. He added that, in this case, we were dealing with a fold rather than with a fault, and that folds often cause more complicated disturbances than faults. He then led the way to the cliff near Holworth House, and pointed out a fault which cuts the cliff in a nearly north and south direction. It is a transverse fault and of less importance in affecting the features of the country, the great lines of disturbance always running in an east and west direction. The section on the east side of the fault shows the junction of the Purbeck and Portlandian strata. The Lower Purbeck here is a flaggy limestone with faint traces of a dirt bed in places and with no marine fossils—indeed, few fossils of any kind. The uppermost Portland rock here consists of a kind of "Roach," a hard Limestone full of casts of marine shells, *Pecten lamellosus*, Sow. ; *Cardium dissimile*, Sow. ; *Pleuromya tellina*, Roem. ; and varieties of *Trigonia gibbosa*, Sow., were amongst the species found by the members. The absence (or rarity) of *Cerithium* serves to distinguish this bed from the typical Roach of the Isle of Portland. Mr. Hudleston said that this change from marine to freshwater conditions, shown in the section, was evidence of some interval between the Portland and Purbeck series, and, in fact, he was certain that an extensive planing of the Portland rocks had taken place in the interval between the deposition of those two formations. The Purbecks rest upon different portions of the Portland rocks in different parts of the country, here on a representative of the Roach, at Portisham on the flinty series. A similar transgression of Purbecks over various members of the underlying Portlands was also noticeable in the Vale of Wardour.

On this Professor Blake said he would make a speculative remark. In the South of France there is a series of beds intermediate between the Jurassic and Cretaceous, which are separated from both as the Tithonic stage. If then we have an unconformity at the top of the Wealden and another at the bottom of the Purbeck the intervening beds might be also separated, as a series corresponding to the Tithonic.

The Portland Beds seen consist of :

1. Roach.
2. Representative of the building-stone.
3. Beds with chert.

The party now passed along the face of an undercliff to a point below Holworth House, where Mr. Hudleston pointed out

blue clay (Gault) resting on the upturned edges of the Jurassic rocks, a splendid example of the great overlap. Immediately above, on the Chaldon Plateau, the overlying Chalk, he said, is fairly level, but a little farther east, for instance at the Durdle, the Chalk and everything else is tilted, and in places even inverted, by the great Isle of Purbeck fold.

The greater number of the party were obliged to turn back at this point in order to catch the official train at Weymouth, but the President and some of the members were able to accompany the Directors on a further examination of the cliffs.

It was not always an easy task to separate the slipped Gault from Kimeridge Clay, and no very definite Gault forms were found, except perhaps *Inoceramus concentricus*, Park. Upper Greensand fossils were abundant. Amongst those collected were, *Pecten asper*, Lam.; *Myacites* (*Panopæa*) *mandibula*, Sow.; *Hamites*, etc.

In the slips of Kimeridge Clay, oil shale was noticed, but the "coal" was not found *in situ*.

The party then walked by the shore westwards to Osmington Mills, where a small stream (the Cascade) flows into the sea. The stratigraphy is sufficiently indicated by Mr. Strahan's figure (Fig. 5).

Mr. Hudleston explained the section, and said that the pre-Cretaceous disturbance, of which such good evidence lay before the party, was exactly in line with the post-Cretaceous disturbance at South Down Farm studied earlier in the day. This is, in fact, the well-known Osmington anticline—a fractured anticlinal fold, which has tilted the Corallian rocks in the bay. He pointed out the connection of the Upton syncline with the Osmington anticline as being parts of a system of folding due to lateral compression.

The party spent some time collecting on the shore and in the cliff, and, as a last effort, proceeded to verify the remarkable lozenge-shaped block of pre-Upper Cretaceous rocks in the defile above Osmington Mills, which is shown in the new Survey Map by Mr. Strahan. There was just sufficient carriage accommodation to enable the party, about twenty in number, to return comfortably to Weymouth.

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N.B.—The 6-inch maps, geologically coloured, are on view in the Museum of Practical Geology, 28, Jermyn Street.

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EXCURSION TO READING.

SATURDAY, APRIL 23RD, 1898.

Director: J. H. BLAKE, F.G.S., ASSOC. M. INST. C.E., OF
H. M. GEOLOGICAL SURVEY.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(Report by the DIRECTOR. Communicated by permission of the Director-General of the Geological Survey.)

SEVERAL members left London at 1.33 p.m., and arrived at Reading at 2.25, where they were met by others from the adjoining districts and from Oxford.

The party walked $1\frac{1}{4}$ miles in a westerly direction to a pit, dug in low-lying valley-gravel, situated on the east side of Elm Lodge. The section showed from 17 to 18 feet of stratified gravel resting on Chalk. The gravel consisted of sub-angular flints, some being of large size and but slightly water-worn, together with a few large, rounded quartzites. A few pieces of broken bone have been found in this pit.

The next excavation visited, belonging to Mr. Jesse, was on the sloping ground a quarter of a mile south of Elm Lodge, and about the same distance south-east of the Barracks. The following was the section exposed:

JULY, 1898.]

DRIFT.	{	Gravel, very coarse, subangular, with many large Quartzites				14 to 16 feet.
		Sand, buff and white, much false-bedded ...				8 to 10 feet.
READING BEDS.	{	BOTTOM BED.	{	Clay, bluish-grey, stratified ...		2 to 2½ feet.
				Oyster-bed		6 to 12 inches.
				Clay, laminated, grey, with green Sand ... ..		... 1½ foot.
				Sand, green, with Clay and Oysters, green-coated Flints at base		3 to 4 feet.
CHALK,* with tubular holes formed by boring molluscs, the holes filled with green Sand.						

The Director explained that the Reading Beds in this district consisted of mottled crimson, grey, and other variegated clays in the upper part, from about 40 to 50 feet in thickness; overlying buff and white sands 20 to 30 feet thick; which latter, rested on stratified bluish-grey clay and olive-coloured green sand, known as the "Bottom Bed," generally from 5 to 8 feet in thickness, but near Newbury as much as 12 feet. Green-coated angular flints invariably occurred at the base of the Bottom Bed at its junction with the Chalk; flint pebbles, small pieces of lydite, and sub-angular green-coated flints were often present a little higher up in the same bed.

In this excavation an impersistent line (about 10 yards in length) of sub-angular green-coated flints occurred in the lower part of the buff sands overlying the "Bottom Bed"; and a similar bed has been noticed in a like position in a sand-pit a short distance to the east of this spot. The upper Oyster-bed was about 2 to 2½ feet down from the top of the "Bottom Bed," and had been exposed on the floor of the pit over an area of about 60 yards by 20; it averaged from 6 to 12 inches in thickness, and seemed to thin out in a northerly direction. The oysters mostly consisted of *Ostrea bellovacina*, Lam., many with both valves united. There were also a large number of oysters, identified by Messrs. Sharman and Newton as *Ostrea gryphovicina*, Wood, several good specimens of which were obtained on this occasion. The largest specimens of *Ostrea bellovacina*, with both valves united, occurred near the base of the "Bottom Bed," and continued upwards for about 3 to 4 feet in the glauconitic, olive-coloured green sand. Mr. Treacher obtained from the Upper Oyster-bed in this pit the following fossils: *Corbula*, *Cytherea*, *Leda*, *Nucula*, *Modiola elegans* (?), Sow., *Tellina* (?), *Cerithium*, *Dentalium*, and *Odontaspis* (*Lamna*) *contortidens*, Ag.

With reference to this Oyster-bed at Reading, extracts from pp. 118 and 119 of Dr. Plots' "Natural History of Oxfordshire," published in 1677, were supplied by Mr. James Parker, and read in the evening by the President. One of the extracts was as follows: "At some places here in England, particularly at

* Exposed in two excavations dug to show the junction with the Reading Beds

Catsgrove [Katesgrove], near Reading, a place sufficiently remote from the sea . . . they meet with a bed of oyster-shells, both flat and gibbous, about 12 or 14 foot underground, not at all petrified, all of them opened, except some very few that I suppose have casually fallen together; which how they should come there without a Deluge, seems a difficulty to most men not easily avoided."

The coarse gravel, which rests on an irregular and water-worn surface of the sands of the Reading Beds, seemed for the most part devoid of stratification. Remains of *Elephas primigenius*, Blum., *Bos primigenius*, Boj., *Cervus*, *Equus*, etc.; and Palæolithic flint implements have been found at various levels in this pit, but are apparently most abundant near the base of the gravel, at about 65 ft. above the level of the Thames in this locality, the surface of the gravel being 81 ft. This was the gravel-pit known as "Hill's-pit," but sometimes described as "Grovelands," in which Dr. Joseph Stevens, Hon. Curator of the Reading Museum, found Palæolithic flint implements for the first time in the Reading district. He shortly afterwards found a large number at a higher level, namely, 119 ft. above the Thames, in a pit on St. Peter's Hill, Caversham, on the opposite side of the Thames. Mr. Llewellyn Treacher and others have since found a large series of implements in the district.

From the above pit the party proceeded in a westerly direction to the extensive excavations connected with Messrs. Collier's Brick and Tile Works. That on the south side of the road, north of the rookery of Prospecthill Park, was first visited, where clay was being dug, and conveyed in buckets on a wire ropeway to the works, about 400 yards to the north. The section was as follows:

LONDON CLAY.	{	Basement Bed, lower part only, consisting of stratified Sand and Clay 4 to 5 ft.
READING BEDS.	{	Mottled crimson, grey, and other variegated Clays, about 30 to 40 ft. Buff and white Sands, false-bedded in places (continuation of those seen in Mr. Jesse's pit) not bottomed about 10 ft. exposed

Some indurated sand resembling "sarsen-stone" was seen in the buff sands, which latter were considered by Prestwich to be one of the parent-sources of the "Sarsens" or "Greywethers." In this case, however, Mr. Young tested the stone and found it to be calcareous.

In another part of the pit a mass of mottled clay was shown in section enclosed in the sands, which the Director considered was probably due to a "pipe" or "swallow-hole" in the chalk, letting down the clay into a funnel-shaped cavity, and thus causing the slickenside so well shown on the mottled clay.

Passing on to Collier's Brick Kilns, the mottled clays and

underlying buff and white sands were again seen, but in a very wavy or undulating condition ; and where one of the steepest bends occurred several small faults were shown. The general dip of the strata is to the south-east, consequently excavations which were being made in a north-westerly direction were rapidly exhausting the capping of mottled clay and approaching the out-crop of the underlying sands.

Westwood Kiln, about 300 yards to the south-west, was next visited. Nearly the whole section showed mottled clays, of considerable thickness, with buff sand cropping out at their base. The Director pointed out a marked feature in the hill, a short distance above the excavation, showing the junction of the London Clay and Reading Beds, the Basement Bed of the London Clay being 10 ft. thick, containing blackish sands, etc. The latter, he added, was a water-bearing bed, and wherever exposed, even in very dry seasons, was generally found in a "weeping" condition.

Leaving the brickyard the party walked by footpath in a north-westerly direction to Norcot kiln, half-a-mile distant. Here a fine vertical section was exposed, showing :

DRIFT.	{	Gravel, pebbly ; Flints, Quartz, many rounded Quartzites derived from Triassic Conglomerates, Lydian Stone, etc.	about 6 ft.
LONDON CLAY.	{	Clay, mottled brown and grey	... .. 5 to 10 ft.
		BASEMENT BED.	{ Sand and Clay interstratified, with white and black Flint Pebbles in brown Sand (in lower part), and casts of shells in ferruginous Sand at and near base	... .. 9 ft.
READING BEDS.	{	Clay, mottled crimson and grey	... .. 7 to 10 ft.
		Sands, buff and white	about 15 ft. had been exposed.

The Basement Bed of the London Clay was well shown right across the section.

Ascending the hill, the members examined the above-mentioned gravel, which forms the Tilehurst plateau, here about 180 feet above the Thames-level, or 300 feet above Ordnance Datum.

The party returned by foot-path to the Barracks, and thence to the Vastern Hotel. After tea a vote of thanks to the Director was proposed by the President, and carried unanimously. The London members caught the 8.30 train, arriving at Paddington at 9.15 p.m.

[It is worthy of note that previous to the year 1896 all excursions to Reading appear to have been whole-day excursions, but on June 13th of that year a half-day excursion was attempted. The sections visited were at and near Katesgrove and Waterloo brickfields, south of Reading, and Mock Beggars brickfield on the east of the town. This excursion proved a success, and when in the present year Mr. Llewellyn Treacher reported that an

interesting and temporary section was open to the west of the town, the Excursion Committee decided in favour of another half-day excursion to Reading. The party numbered about 26, and the excursion may, therefore, be looked upon as a decided success. These details are mentioned, as long-distance, half-day excursions are still somewhat in the nature of experiment.

HORACE W. MONCKTON, *Sec. (Excursions).*]

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EXCURSION TO AYOT GREEN AND HATFIELD HYDE.

SATURDAY, MAY 14TH, 1898.

Directors: JOHN HOPKINSON, F.G.S., ASSOC.INST.C.E., AND
A. E. SALTER, B.Sc., F.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by the DIRECTORS.*)

THE party left King's Cross at 1.20 p.m., and by 2.30 the Directors were discoursing in Ayot Brickfield on the strata there exposed. It was pointed out that Ayot Green is situated on high ground (380 ft. to 406 ft. O.D.) between the valley of the Lea and that of its affluent the Mimram. The Lea rises near Houghton Regis, a little above 400 ft. O.D., on the Luton Gap, and flows through the town of Luton before it enters Hertfordshire; the Mimram makes its first appearance as a pond at Whitwell near St. Paul's Walden, scarcely 300 ft. O.D., flows by Welwyn and under the Digswell Viaduct of the Great Northern Railway, and
JULY, 1898.]

joins the Lea at Hertford. About eight miles due north of Ayot Green, the Chalk Downs are breached by the Hitchin Gap at 305 ft. O.D., and it was remarked that the next lowest gap on the west was that at Goring, 160 ft. O.D., while to the east, one existed north of Bishop's Stortford at 230 ft. O.D. The position of these gaps is regarded by Mr. Salter as of great importance in all questions relating to the origin of the drift deposits in the Thames Basin.

The geological structure of the district was next described. It was pointed out that the Ayot Brickfield is situated on one of the many Tertiary outliers, resting on the Chalk, which fringe the Thames Basin both on the north and on the south. In most cases, if not in all, they are capped by beds of gravel, to the presence of which their preservation may chiefly be ascribed. The outliers at Penn and Coleshill between High Wycombe and Amersham, Tyler's Hill or Cowcroft near Chesham, Bennett's End, Hemel Hempstead, and Bernard Heath, St. Albans, on the north-west of the London Basin, may be cited as similar examples, while Well Hill is an example of such an outlier occurring on the south. Mr. Hopkinson drew attention to the remarkably straight line formed by the outliers on the north by means of a strip of paper twelve times as long as it was wide, on which he had drawn nearly all the outliers which extend from Wargrave, beyond Maidenhead, on the south-west, to Albury, near Bishop's Stortford, on the north-east, a distance of fifty miles. They are almost exactly in the line of strike of the Chalk, and he referred to the theory that they mark a slight deflection of the dip of the underlying strata, though, as they now form the highest land, it was strange if this line of Tertiary beds owed its preservation from denudation at an early period, as was supposed, to having lain in a hollow in the Chalk. At any rate, the existing outliers are probably fragments of a once more-continuous band, owing their individual preservation at a later period and to the present time to the greater resistance to sub-aërial denudation offered by the gravel by which they are mostly capped, than that of the Chalk by which they are surrounded.

Some of these outliers are of the Woolwich and Reading Beds only; others have also upon these beds the London Clay, sometimes only its Basement Bed. Here the Reading Beds consist of sands with numerous clayey partings. The Chalk below is piped, and the Tertiary Beds above have been irregularly let down, giving them quite a contorted appearance on the north side of the brickfield, while on the south they are overlain by the London Clay, and although not here seen, we may infer that this clay has so far prevented the percolation of water into the Chalk that pipes are absent and the Reading Beds are but little disturbed.

In the Basement Bed of the London Clay, teeth of *Lamna* and casts of bivalves are to be obtained, but the bed of flint-pebbles in which these occur was nearly all covered up by *débris*. The best time to find fossils is in winter when the clay is being dug out. This is the lowest layer of the Basement Bed. There is another thin layer of flint-pebbles near the top in which oyster-shells are occasionally found.

Covering the Tertiary Beds were seen Drift gravels, which in one part are remarkably similar in composition to typical Westleton Shingle, and at this point Boulder Clay rests upon them, containing erratics of a simpler character than does the Boulder Clay at Hatfield Hyde.

In Griggs' Wood, a little to the north and on rather higher ground, the highest in the immediate neighbourhood, a characteristic section of Westleton Shingle was seen, and the simple character of its constituents and their similarity to those found at South Mimms, High Barnet, etc., were pointed out.

After a pretty walk of three miles through Sherrard's Park Wood, the large excavation by the side of the Great Northern Railway at Hatfield Hyde was reached. Here about 42 ft. of Glacial deposits are exposed, consisting of the following :

(a) A thick bed (12 ft.) of Boulder Clay containing much chalk in its lower part and *débris* from the Midlands, e.g., *Gryphææ*, *Belemnites*, and Triassic and other pebbles.

(b) About 15 ft. of sands, with patches of gravel containing similar *débris*.

(c) A lower bed of Boulder Clay 1 ft. thick, similar in character to (a).

(d) Ochreous flint-gravel and sands with Triassic quartzites (about 15 ft.).

(e) Chalk, disintegrated.

This interesting section, which has not before been visited by the Association, had been brought to the notice of the Directors by the Rev. H. G. O. Kendall, M.A., who, assisted by the local branch of the Selborne Society, had thoroughly investigated the pit. Specimens which had been carefully collected from the various layers were displayed for inspection. One specimen, of polished Carboniferous Limestone, finely striated and showing sections of Crinoid stems, was especially interesting. The pit is situated at about 290 feet O.D., a mile north of the Lea, and just before it takes a bend from south-east to east.

An enjoyable walk through the woods which fringe the north-west corner of Hatfield Park, in the course of which the Lea was crossed at the point where it is expanded into an ornamental sheet of water, followed by tea at the Red Lion, Hatfield, brought a most successful excursion to a close.

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EXCURSION TO PENN AND COLESHILL, BUCKS.

SATURDAY, MAY 21ST, 1898.

Director: W. P. D. STEBBING, F.G.S.

Excursion Secretary: MISS M. C. FOLEY, B.Sc.

(*Report by the DIRECTOR.*)

ON arrival at Loudwater at 3 p.m., the Director led the party up the hill S.W. of Loudwater to some sections mapped “Glacial Drift.” These openings, at about 350 ft. above O.D., show about 7 ft. of clayey gravel made up of sub-angular flints, flint-pebbles from the Eocene pebble-beds, and a few boulders of quartz and quartzite. One particularly large quartz boulder seen, measured about 2 ft. × 14 in. × 12 in.

Returning past the station, the party next visited a pit in a bed of sand and gravel which rests on the Chalk on the slope of the hill to the N.E. of Loudwater. This pit, also mapped “Glacial Drift,” and at about the same height as the former, shows stratified sand and gravel, occurring irregularly. The gravel consists mostly of water-worn material of all sizes; large pebbles of quartz and quartzite are common, and pebbles of black chert occur. The sand in places is clayey, with thin seams of clay. At the eastern end of the pit, a pinnacle of chalk, surrounded by black clay with un-rolled flints, protrudes into the sand; it has a curious effect, but Mr. Monckton thought that it was merely part of the side of a swallow-hole.

Thence the members walked to Tyler’s Green, passing, S. of Penn, the junction of the Chalk and the Reading Beds, which was not seen, though evidence of the presence of clay was shown by several small ponds.

Penn is one of the line of Tertiary outliers that runs nearly in a north-easterly direction from Greenmore to Bennington. These
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outliers are probably due to their position along the line of a slight trough, which has preserved them from denudation.

At Tyler's Green, which lies just to the W. of Penn, a gravel-pit was inspected, by kind permission of the Rev. Mr. Spencer. This pit, situate about 550 ft. above O.D., shows: (1) Brick-earth of irregular thickness up to 4 ft.; (2) Stratified, sandy gravel (about 8 ft. seen), made up of pebbles of flint, with a fair proportion of small quartz pebbles. There were also a number of large sub-angular flints. The pebble-gravel in this pit is supposed to be the equivalent of the Westleton Shingle of Prestwich, but it was thought by some of the party that if the large sub-angular flints came from the gravel, it could not be Westleton Shingle.

As time pressed, Penn church and one or two small sections in its vicinity could not be visited, and the walk was continued to Coleshill, where, in March last, a section about 500 ft. above O.D., showing 10 ft. of Reading Beds (mottled and dark blue clay), capped by pebble gravel, had been seen by the Director; but since that time the pit had been almost filled up, and only about 2 ft. of the mottled clay was discernible, covered by the gravel (Westleton Shingle), which consists of rolled flint and quartz pebbles, small rolled pieces of puddingstone, and much fine quartz. London Clay caps the Coleshill outlier, but, as the Director had not seen or heard of any open sections in it, the members made their way without delay to Amersham for tea. After tea, the President heartily thanked the Director, who replied, and the party returned to London by the 8.13 train.

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NOTE.—The Association is much indebted to Mr. Stebbing for the trouble he took in arranging this excursion. So far as I know, we have not previously visited the district, and the sections seen were of much interest.—H.W.M.

SKETCH OF THE GEOLOGY OF THE BIRMINGHAM DISTRICT.

WITH SPECIAL REFERENCE TO THE LONG
EXCURSION OF 1898.

BY PROFESSOR C. LAPWORTH, LL.D., F.R.S.,

WITH CONTRIBUTIONS BY PROFESSOR W. W. WATTS, M.A., SEC. G.S., AND
W. JEROME HARRISON, F.G.S.

PLATES X, XI, XII.

[Read July 1st, 1898.]

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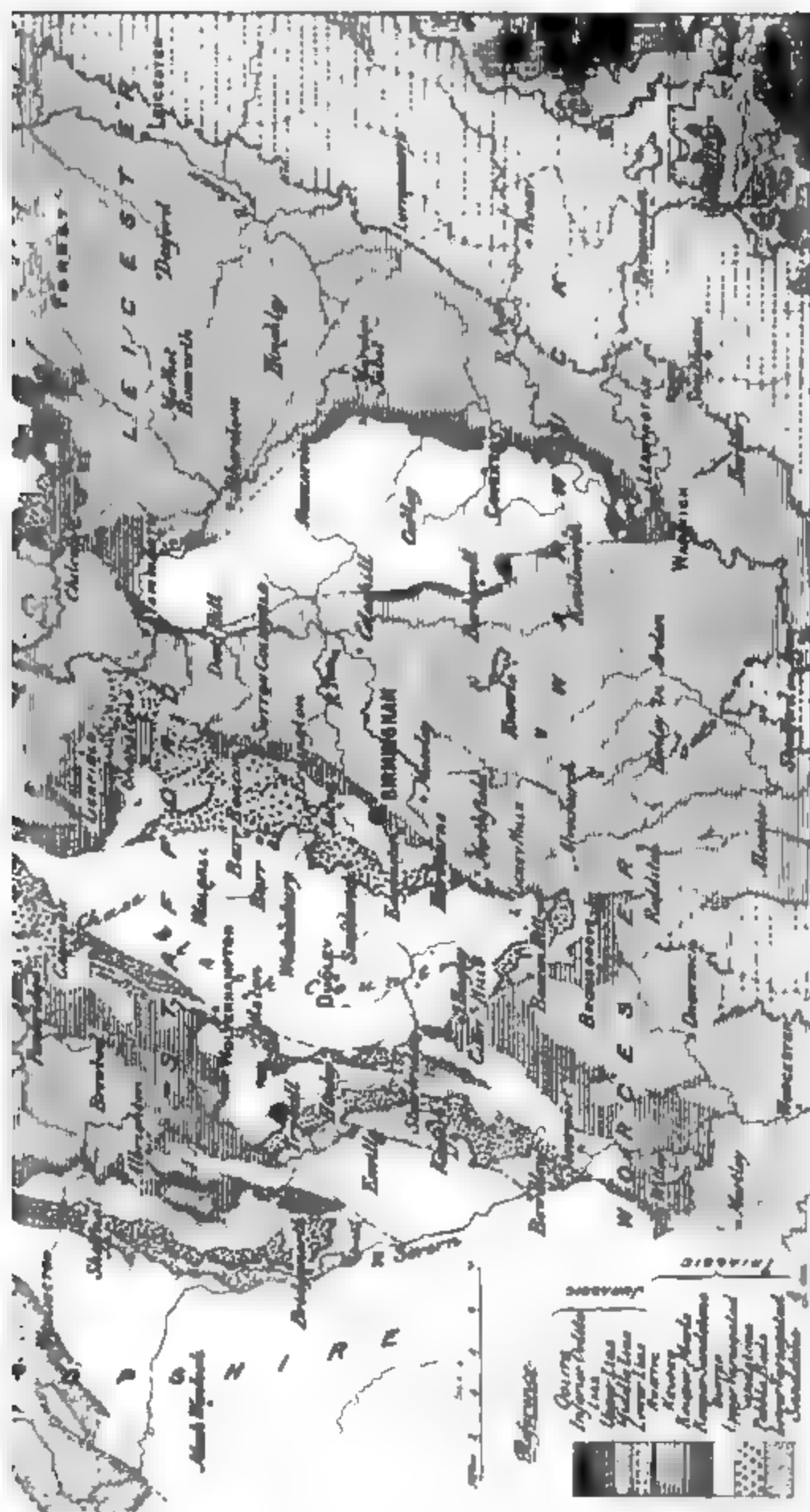
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INTRODUCTION.

I. Physiography.

THE City of Birmingham lies almost exactly in the geographical centre of England and Wales. Its distance from the three nearest seaports on the opposite sides of the island, Liverpool, Bristol and Boston, is about eighty-five miles in each case; and its distance from London, Hull, and Southampton is only a few miles more.

The region which we denominate the "Birmingham District," is included within a radius of about thirty-five miles from the city. Within this radius we have not only the populous area of the *Black Country*, with the large towns of Wolverhampton, Dudley, Walsall, Wednesbury, and West Bromwich; but also the more distant towns of Worcester, Malvern, Wellington, Stafford,
AUGUST, 1898.]



MAP 1.—MESOZOIC ROCKS OF THE BIRMINGHAM DISTRICT.

(Black Amt by Prof. Lapworth.)

Burton-on-Trent, Leicester, Nuneaton, Warwick, Leamington, Tamworth, Coventry, and others.

The main watershed of Southern Britain, which divides the rivers flowing eastwards into the German Ocean from those which flow westwards into the Irish Sea and the Bristol Channel, runs obliquely through the centre of the Birmingham District from north-west to south-east. This watershed enters upon the District near the town of Newport in Shropshire, crosses the south-western portion of the Black Country obliquely along the line of the Dudley Hills, and sweeps in a sinuous course across the Midland plain, south of Birmingham and north of Coventry, to the head waters of the Avon beyond Lutterworth. The land to the north and east of this line lies within the basin of the Trent; that to the west and south within the basin of the Severn.

The *Trent* itself merely crosses the central parts of the northern section of the District, in its course from Stafford to Derby round the southern flanks of the Pennine Chain; but three of its tributaries are of special importance in the drainage of the Birmingham District. Of these the chief is the *Tame*, which rises in the Black Country, flows immediately north of Birmingham, and drains with its many affluents all the land lying between the Black Country and Charnwood Forest. A second tributary, the *Soar*, drains the region lying east and south of the Forest, and a third, the *Penk*, the area lying north-west of the Black Country.

The *Severn* enters the Birmingham District through the gorge of Coalbrookdale, and its deep river valley, widening greatly as it is followed to the south, sweeps in a gentle curve through the western parts of the district, out of which the Severn passes between Worcester and the Malverns, on its course to the Bristol Channel. Several tributary streams, such as the *Worf* and the *Stour*, run in sub-parallel courses west of the Black Country, and empty their waters into the Severn; but the tributary which plays the most important part in the physiography of the land is the Warwickshire *Avon*. This drains the whole of the south-eastern division, and next, perhaps, to the *Tame*, may be said to be the characteristic river of the Birmingham District.

It is the habit of geographers to speak of the Birmingham area as forming the heart of the so-called Great Midland Plain of England and Wales. But only in a general and relative sense is this description accurate; for, considered as a whole, the Birmingham District is by no means plain-like. It may rather be defined as including those central and higher parts of the diversified Midland areas from which radiate the three chief river-plains of England—the plain of the Mersey and Dee to the north-west, the plain of the Trent and Humber to the north-east, and the plain of the Avon and Severn to the south-west. Generally speaking, the

Birmingham District is a land of gentle heights and open valleys ; its numberless, broad, mound-like hills are divided from each other by wide stream valleys, which are usually just deep enough to give point and character to the swelling grounds between.

The *watershed* which divides the basins of the Severn and Trent, and forms what may be called the natural geographical axis of the district, is by no means a prominent feature in its physiography. Only for a few miles, about midway along its course, namely between Sedgley and Rubery, does it coincide with a chain of heights or even form a dominant feature in the landscape. Here, however, the watershed runs along the summits of a conspicuous range of hills—including those of Sedgley, the Wren's Nest, Dudley Castle Hill and Rowley—a range which crosses the South Staffordshire Coalfield obliquely from side to side, and is continued to the south-eastward along the rolling heights east of Halesowen into the wedge-like chain of the Lower Lickeys. Elsewhere the Midland watershed wanders vaguely and irregularly across the District from one broad swell to another, and nowhere does it rise to a greater height than some 800-900 ft. above the level of the sea.

Along the south-eastern limits of the Birmingham District sweep the Jurassic scarps and terraces of the Cotteswold and Edge Hills. These gradually decline in height as they are followed to the north-east from Cheltenham, past Harbury and Rugby to Leicester and Loughborough ; while just inside the district itself, and running parallel with these scarps, we have the soft river valleys of the Soar and the Avon. The former opens into the plain of the Trent, near Stoke and Nottingham, the latter merges into the plain of the Severn between Tewkesbury and Gloucester.

Along the west of the district rise the broad uplands of Hereford and Shropshire, with the conspicuous points of the Wrekin to the north-west, the Clee and the Abberley Hills near the centre, and the long, narrow ridge of the Malverns to the south-west. Shutting off this upland region from the Birmingham District proper runs the most striking and continuous of the Midland depressions—the long and deep groove formed by the valley of the Severn.

Into the north of the district project the southern spurs of the Pennine Range, round which swings in a long semicircle the broad river-valley of the Trent. To the extreme north-east the ground sweeps upwards from the rolling plains around into the bold and breezy upland region of Charnwood Forest, whose culminating point of Bardon Hill (902 ft.) overlooks the whole of the eastern half of the Birmingham District.

Inside the Birmingham District itself the physiography is somewhat more complicated. The core of the western half of the district is formed by the South Staffordshire Coalfield, which is crossed by the conspicuous range of the Dudley

Hills, already mentioned. Except for this dividing ridge, the ground within the coalfield is more or less low and plain-like, and the countless mines, chimneys, straggling villages and towns, usually all shrouded in a pall of smoke and steam, have conferred upon it the well deserved title of the "Black Country."

This Black Country is surrounded by an almost continuous frame or border of high ground, the steeper scarps of which are turned inwards toward the centre of the coalfield, and the more gentle slopes outwards toward the open plains beyond. The highest parts of this hilly framework lie on the extreme south of the coalfield, where they form the long and continuous chain of the Lickey and the Clent Hills; which rise near their south-eastern extremity in the Bromsgrove Lickey to a height of about 900 ft. above sea level, and in the Clent Hill, near their north-western termination, to a height of 1,028 ft. East of the coalfield the hilly framing is formed by what—for want of a better name—we may term the Birmingham Plateau. This ranges northward from Frankley Beeches, near the Lower Lickey, almost to the valley of the Trent, near Rugeley. Its highest point is Barr Beacon (710 ft.), which overlooks the central parts of the coalfield. Upon this plateau, which is locally several miles in breadth, stand Birmingham and its dependencies, the town of Sutton Coldfield, and the city of Lichfield. The rolling surface of the plateau is often richly wooded, and is in striking contrast with the barren Black Country to the west. Along the western side of the Coalfield the marginal framing of hills is less continuous. To the northward, however, it becomes again almost as conspicuous as on the south, and rises to heights of from 779 to 787 ft. above the level of the sea in the wild upland district of Cannock Chase.

Turning next to those parts of the Birmingham District which lie outside the limits of the South Staffordshire Coalfield and its hilly margin, we find that to the west of the Black Country the surface of the district is remarkably varied. Long and conspicuous ridges, divided by narrow river valleys and ranging more or less parallel with the western edge of the coalfield, follow one behind the other, mile after mile, until the series is closed at last by the main valley of the Severn. To the south of the coalfield the Clent and Lickey Hills look out far and wide over the conjoined plain formed by the Lower Avon and Severn toward the distant heights of the Malverns and Cotteswolds. East of the Birmingham Plateau the surface of the country dies down gently into a broad area of softly-rolling ground—the site of the old Forest of Arden—ranging from Tamworth on the north, past Solihull, Coleshill, and Henley-in-Arden to Stratford on the south, and watered by the many brooklets tributary to the Tame and the Avon.

The physiography of the eastern half of the Birmingham District is far less pronounced than that of the western half already described. A long and low swell of high ground fills up

the country lying between Tamworth and Coventry, Atherstone and Kenilworth, but nowhere attains an elevation of more than 570 ft. (High Ash) and 580 ft. (Bentley Wood) above the level of the sea. Still, farther to the eastward, a gently rolling country, very similar in its characters to that of the Forest of Arden, occupies all the ground between Nuneaton and Leicester, and forms the so-called plain of Central Leicestershire.

II.—Geology.

One of the most salient and best-known features in the general geology of Britain is afforded by the fact that the outcrops of its geological formations form a series of sub-parallel bands which range across the island in a S.W. and N.E. direction from sea to sea. In England, however, this orderly succession of parallel bands, which is the result of the general south-easterly inclination of the strata of the successive geological systems, is twice rudely interrupted. These interruptions are due to the existence of two grand anticlinal forms, which have had the effect of splitting the outcrop of some of the formations into two distinct arms, one of which follows the usual south-west and north-east course, while the second proceeds in an entirely different direction. Where the two arms unite, the superficial breadth of the outcrop of the geological formation which is affected is practically doubled for the time, and we have the widest spread of scenery which is typical of that formation.

The first of these anticlines is that of the Weald, which ranges east and west through the south-east of England. This anticline adds a long east and west arm of Upper Cretaceous to the ordinary S.W. and N.E. outcrop of the rocks of the system. Where the two arms of the Chalk unite in North Hampshire and Wiltshire we have the broadest expanse of Cretaceous outcrop and the widest spread of typical Chalk scenery, in the dry and rolling expanse of Salisbury Plain.

The second and even more important anticline of Southern Britain is that of the Pennine Range, which runs north and south from the Cheviots of the Scottish Borderland to Derby in Central England. This anticline takes its greatest effect on the outcrop of the Triassic system—the typical system of Central England. The ordinary outcrop of this system is split by the Pennine axis into two main arms, one of which is prolonged more or less in the original N.E. direction across Nottingham and Yorkshire to the mouth of the Tees; while the other is turned sharply to the north-westward, and is prolonged through Cheshire and Lancashire to the valley of the Solway.

Where the two arms of the Triassic outcrop unite, south of the anticline of the Pennines, the Triassic system attains its widest

SHROPSHIRE. STAFFORDSHIRE. WARWICKSHIRE. S.E.

Wrockwardine. Wellington. Wrekin. Coalbrookdale. Shifnal. Codrall. Wombourne. Castle Hill. Dudley. Oldbury. Birmingham. Solihull. Knowle. Rowington. Warwick. Harbury.



FIG. 3.—SECTION THROUGH THE BIRMINGHAM DISTRICT FROM NORTH-WEST TO SOUTH-EAST (WELLINGTON TO HARBURY).—C. Lapworth.

Li. Lias. Rh. Rhætic Series. K². Keuper Marls. K¹. Keuper Sandstone. B. Bunter. P. Permian. C³. Coal Measures. C¹. Carboniferous Limestone. Si. Silurian. Cm. Cambrian. A. Archæan.

C. LAPWORTH ON THE

HEREFORDSHIRE. MALVERN HILLS. WORCESTERSHIRE. LICKLEY HILLS. WARWICKSHIRE. CHARNWOOD FOREST. LEICESTERSHIRE. S.W. N.E.

West Malvern. North Hill. Worcester. Droitwich. Bronsgrrove. Upper Lickley. Rubery. Northfield. Knowle. Arley. Stockingford. Nuneaton. Market Bosworth. Bardon Hill. Mt. Sorrel.



FIG. 4.—SECTION THROUGH THE BIRMINGHAM DISTRICT FROM SOUTH-WEST TO NORTH-EAST (MALVERN HILLS TO CHARNWOOD FOREST).—C. Lapworth.

K². Keuper Marls. K¹. Keuper Sandstone. B. Bunter. P. Permian. C³. Coal Measures. C¹. Carboniferous Limestone. Si. Silurian. Cm. Cambrian. A. Archæan.

Si. Silurian. Cm. Cambrian. A. Archæan.

geographical extension in Southern Britain. It here presents us with its most varied and characteristic scenery, and constitutes the very heart of the English Midlands. The width of this expanse of Triassic surface, along a line drawn east and west a few miles north of Leicester and Shrewsbury, is fully fifty miles. As we pass southwards, however, the width rapidly decreases, until, when we reach the neighbourhood of Worcester and Gloucester, some fifty or sixty miles to the south, the diameter of the Triassic outcrop, between the Palæozoic strata to the west and the Liassic strata to the east, is less than ten miles.

This grand triangular spread of Triassic rocks is almost completely included within the limits of the Birmingham district ; so that the Triassic is not only the dominant and characteristic geological system of the District itself ; but constitutes, as it were, the natural geological datum to which all the more salient phenomena in its geology, its scenery, and its economics are most naturally referred.

To the *westward* this sheet of Triassic rocks rests unconformably upon the edges of the Palæozoic formations, the Silurian, Old Red Sandstone, Permian, etc., along an irregular line running more or less north and south from Lilleshall, down the valley of the Severn, to the eastern flanks of the Abberley and Malvern Hills. *Eastward* and south-eastward the highest Triassic strata pass up conformably through a thin, but well-marked development of the Rhætic formation, into the basement beds of the Jurassic, the line of junction following a general north-east and south-west course from Loughborough, Leicester, Rugby, Harbury, Stratford, and Droitwich, to Tewkesbury and Gloucester. *Northward*, the Triassic sheet laps round the southern edge of the Pennine anticline, as already described, reposing unconformably upon the Permian and Carboniferous rocks.

The outcrops of the strata of the Triassic System within the great triangular area thus limited, unlike those of the newer Jurassic rocks to the east, do not form a continuous and unbroken expanse ; for the rocks of the system have been bent up by several subordinate anticlinal forms, from the crests of which the originally overlying Triassic strata have been denuded, and the underlying Palæozoic rocks laid bare. It is true that the great Pennine anticline which divides the main outcrop to the northward appears to die away suddenly in the valley of the Trent ; but in its stead there arise four minor anticlinal forms, the axes of which radiate, as it were, like a pencil of rays from the southern extremity of the Pennines, and these traverse and warp up the great spread of Triassic in the Birmingham District to the south.

The first of these anticlinal forms is that of the *Wrekin*, which proceeds to the south-westwards through the Trias of Cheshire and N. Staffordshire into the Wrekin Hills, near

Wellington, and is continued through Central Shropshire, Hereford and South Wales. The second is that of *South Staffordshire*, which ranges nearly north and south from the Peak through Cannock Chase, Dudley, and the Lickey Hills to the Jurassic strata of Worcester and Gloucester. The third is that of *East Warwickshire*, which is most conspicuous in the central parts of the district between Tamworth and Coalbrookdale. The fourth is the irregular dome of *Charnwood and Ashby*, which traverses the country lying between Derby and Leicester.

From the crests of each of these four anticlines the Permian rocks, etc., have been denuded, and the workable Coal Measures laid bare. In the Wrekin area we have the Coalfields of *Coalbrookdale* and the *Forest of Wyre*. The rise of the Staffordshire anticline has brought to the surface the rich Measure area of the *South Staffordshire* Coalfield. The *Warwickshire* Coalfield forms a part of the East Warwick anticline, and the Coalfield of *Leicestershire* is connected with the denuded anticline of Charnwood and Ashby.

The long and narrow range of the *Abberley and Lichfield* Hills, which runs almost exactly north and south along the south-western borders of the Birmingham District, may be regarded as constituting a fifth anticlinal form; but it lies on the outer margin of the district and forms the extreme boundary of the Trias in the Midland area. Like the other anticlines of the district, however, this fifth one is marked by the occasional presence of workable Coal Measures.

In all these Midland anticlines, bands and patches of Permian strata, often of remarkable characters, intervene between the Coal Measures and the enveloping Triassic strata. These Permian rocks sometimes cover large areas of country, as in the district between Tamworth and Coventry, and elsewhere.

The post-Triassic denudation along the crests of these land anticlines has, in the majority of cases, not only been sufficient to lay bare the Permian strata, and the underlying Carboniferous rocks which constitute the Midland Coalfield, but it has often been carried to such an extent as to sweep away large areas of the Coal Measures themselves and to expose older geological formations, even in some instances the Archaean or basement rocks of the geological scale.

Along the Wrekin and its connected anticlinal forms the Severn not only is the Trias wholly wanting, but the continuous expanse of Carboniferous strata, which once seemed to have overspread that region, is now reduced to a narrow, irregular outcrop ranging down the valley of the river from Coalbrookdale to Stourport, and to a few isolated patches resting upon the Old Red Sandstone strata high up

summits of the Clee Hills. On the flanks of the Wrekin, Malvern, and Abberley Hills themselves erosion has laid bare the Silurian and the Cambrian, and in their inner cores a great thickness of pre-Cambrian igneous and metamorphic rocks.

The anticline of the South Staffordshire Coalfield has brought to the surface the Silurian at Dudley and Walsall ; and the Silurian, Cambrian, and Archæan in the Lower Lickey Hills. The Triassic and Carboniferous rocks of East Warwickshire have been stripped from the Cambrian and pre-Cambrian rocks of Nuneaton and Caldecote. Finally, in the upland district of Charnwood Forest the flat-lying Keuper Marls have been denuded from off the higher grounds, exposing many remarkable inliers of steeply-dipping Archæan rocks.

But, great as this post-Triassic denudation has been, the proportion of the surface of the Birmingham District occupied by outcrops of strata older than the Carboniferous is relatively small. If we except the Palæozoic region lying to the west of the Severn, the pre-Carboniferous rocks of the Midlands are restricted to very small areas of country, and occur only in long bands less than a couple of miles in width—as in the Malverns, the Abberleys, the Lickeys, and at Hartshill ; or they are met with in small hill ranges surrounded by broad expanses of newer rocks, as in the hills of Dudley and in Charnwood Forest.

THE LOCAL ROCK FORMATIONS.

If we regard the Birmingham district as extending in the one direction to the Stretton country, and in the other to the town of Northampton, the geological formations within its limits embrace the entire geological succession between the pre-Cambrian and the Inferior Oolite. Two rock systems, however, are wanting in the central and eastern parts of the district, namely, the *Ordovician* and *Old Red Sandstone*. The outcrops of Ordovician strata which lie nearest to Birmingham occur in Central Shropshire, about 45 miles north-west of the city ; and the nearest exposures of the Old Red Sandstone are met with in the Shatterford district, near Enville, some 18 miles to the south-west.

The formations recognised, and the localities where their strata are displayed, are given in the following table :

TABLE OF THE GEOLOGICAL FORMATIONS OF THE
BIRMINGHAM DISTRICT.

Mesozoic Rocks.

OOLITE	...	...	<i>Inferior Oolite</i>	...	...	Daventry.
LIAS	...	...	<i>Upper Lias Clays</i>	...	...	Daventry, Catesby.
			<i>Middle Lias</i> (Marlstone)			Edgehill, Daventry.
			<i>Lower Lias Clays</i>	...	...	Harbury, Rugby, etc.

RHÆTIC ...	...	Harbury, Wootton Wawen, Knowle, Leicester, Barrow, Needwood Forest.
TRIAS		
(UPPER TRIAS OF KEUPER) ...	<i>Upper Keuper Marls</i> ...	Leamington, Stratford, Worcester.
	<i>Upper Keuper Sandstone</i>	Henley - in - Arden, Shrewley, Leicester.
	<i>Lower Keuper Marls</i> ...	Droitwich, Stoke Prior, Redditch, Moseley, Atherton, Leamington, Penkridge, Bednall, Burton-upon-Trent.
	<i>Waterstones or Lower Keuper Sandstones.</i>	Birmingham, Lichfield, Sutton Coldfield, Tamworth, Coventry, Warwick, Bromsgrove, Hagley, Stourbridge, Tetterhall, Penkridge, Rugeley.
(LOWER TRIAS or BUNTER) ...	<i>Upper Variegated Sandstone.</i>	Burcot, Catshill, Stourbridge, Penley, Claverley, Harborne, Edgbaston, Aston, Shenstone.
	<i>Pebble Beds (or Bunter Conglomerate).</i>	Bromsgrove Lickey, Smethwick, Barr, Sutton Park, Cannock Chase, Shifnal, Overseal, Kidderminster.
	<i>Lower Mottled Sandstone</i>	Enville, Bridgenorth, Shifnal.

Palæozoic Rocks.

PERMIAN ...	...	<i>Upper Permian Sandstone</i>	N.E. of Enville, Bobbington.
		<i>Middle Permian and Permian Breccia.</i>	Clent Hills, Romsley Hill, Stourbridge, Stourport, Abberley, Malverns.
		<i>Permian Red Sandstones, Marls, and Conglomerates.</i>	Coventry, Kenilworth, Corley, West Bromwich, Brand Hall, Baggeridge Wood, Bushbury, Bridgenorth, Shifnal, St. Kenelms.
CARBONIFEROUS...			
		<i>Upper Coal Measures, with Spirorbis Limestone Group.</i>	Stockingford, Arley, Kingsbury, Halerowen, Forest of Wyre, Coalbrookdale.
		<i>Lower Coal Measures, with workable coal seams.</i>	<i>Leicestershire Coalfield</i> , Ashby, Coalville, Moira. <i>East Warwickshire Coalfield</i> , Bedworth, Stockingford, Polesworth. <i>S. Staffordshire Coalfield</i> , Dudley, Oldbury, Pelsall, Hednesford. <i>Forest of Wyre Coalfield</i> , Kinlet. <i>Coalbrookdale Coalfield</i> , Coalbrookdale.
		<i>Millstone Grit</i>	...
		<i>Carboniferous Limestone</i>	...
			Ashby, Coalbrookdale, and Clee Coalfields only.
			Clee Hills, Coalbrookdale, Wrekin, Bredon.

OLD RED SAND- STONE	Cleobury Mortimer, Abberley, Shatterford (absent in centre and east of district).
SILURIAN ..	<i>Lullow Shales and Limestones.</i> Sedgley Hill, Abberley Hills, Malverns.
	<i>Wenlock Limestone and Shales.</i> Dudley Castle Hill, Wren's Nest, Walsall, Malverns, Abberley.
	<i>Woolhope Beds</i> Rubery, Barr, Kendal End, Abberley, Malvern.
	<i>Upper Llandovery May Hill.</i> or Malvern and Abberley Hills, Lickey Hills, Rubery, Barr, Coalbrookdale.
ORDOVICIAN	Onny River, Cardington (absent at the surface except in Central Shropshire).
CAMBRIAN ...	<i>Cambrian Shales</i> ... Stockingford and Merevale, Wrekin, Shineton, South Malverns, Dosthill.
	<i>Cambrian Quartzite</i> , etc. Hartshill, Nuneaton, Lickeys, Wrekin, Malvern Hills.
PRE-CAMBRIAN or ARCHÆAN	Malvern Hills, Charnwood Forest, Caldecote, Barnt Green, Wrekin, and Ercall.
INTRUSIVE IGNE- OUS ROCKS ...	of various geological ages Malvern Hills, Clee Hills, Rowley Regis, Pouk Hill, Atherstone, Griff, Sapcote, Markfield, etc.

Although Ordovician strata are not certainly known to occur at the surface within the limits of the Birmingham District, except near the western edge, it is possible that some of the members of the system once existed *in situ* within it. Pebbles of Ordovician rocks, with fossils of species similar to those of the arenaceous members of the French succession of Brittany and Normandy (*Armorican Sandstone* and *Grès de May*), are occasionally met with in the Bunter Pebble Beds of the Midlands, as in the case of the corresponding Pebble Beds of Budleigh Salterton. The Old Red Sandstone of the western parts of the district, as a general rule, retains its well-known Herefordshire characters throughout those areas where it occurs. From the following detailed descriptions of the various geological formations which are met with in the District references to the Ordovician and Old Red Sandstone are omitted.

Archæan or Pre-Cambrian.

The ancient rocks which form what may be termed the "basement" of the Birmingham district, and underlie all the fossil-bearing geological formations are, for the most part, hidden from sight by these overlying formations. In a few areas, however, the formerly overlying rocks have been swept away

by denudation, and the fundamental rocks of the basement floor laid bare. These exposures occur only along the axes of some of the chief anticlinal forms, and they are for the most part of insignificant extent. Three of the areas of fundamental rocks, namely, those of (1) *The Malvern Hills*, (2) *The Wrekin Hills*, (3) *Charnwood Forest*, include the highest points of the Birmingham district, but they lie along its outer margins. The Malvern Hills rise along the extreme south-western border of the Birmingham district; the Wrekin Hills lie just within the limits of the district to the extreme north-west; while the hills of Charnwood Forest practically form its north-eastern extremity. Only two exposures of these Basement Rocks occur well within the borders of the district itself, namely, the inlier of (4) *Caldecote*, which lies along the north-eastern edge of the Cambrian area of Nuneaton, and (5) the inlier of *Barnt Green*, which lies at the south-eastern extremity of the Lower Lickey Hills.

Of late years it has been the general practice of Midland geologists to group all the Basement Rocks exposed in these inliers as of Archæan (or pre-Cambrian) age; and there can be little question that this view of their high geological antiquity is that which best accords with the known stratigraphical phenomena. The lowest Cambrian of the West of England and the Midlands, as developed in the Wrekin-Caradoc area, is made up of a thick sheet of quartzite (*Wrekin Quartzite*) graduating through some shaly and calcareous beds into a thinner sheet of grit, the *Hollybush Sandstone*. The Basement Rocks of the inlier of the Wrekin underlie this Cambrian Quartzite unconformably, and their pre-Cambrian age—first suggested by Dr. Callaway—has long been acknowledged. Again, the Hollybush Sandstone rests upon the Basement Rocks of the Malvern Hills, and its lowest zone contains well-rounded pebbles derived from their ruins, so that the correctness of the view of their Archæan age—first asserted by Dr. Holl—is now generally conceded. The Basement Rocks of the Caldecote inlier rise out from below the Hartshill Quartzite of Nuneaton—which is, in all probability, continuous with the Cambrian Quartzite of the West of England—so that these Caldecote Rocks are most naturally to be regarded as the equivalents of those Archæan Rocks which rise from below the Quartzite of the Wrekin. The Basement Rocks of Barnt Green appear to hold a corresponding relationship to the Cambrian Quartzite of the Lower Lickey Hills, and may be looked upon as in all likelihood of Archæan age upon similar grounds. On the other hand, however, the Basement Rocks of the Charnwood area are surrounded on all sides by Trias, so that no stratigraphical proof is forthcoming, in their case, of so high a geological antiquity. The lithological peculiarities of these Charnwood Rocks, however, ally them more to the Archæan Rocks of the pre-Cambrian inliers already mentioned

than to any of the Cambrian or post-Cambrian strata, and Midland geologists have long since accepted Prof. Bonney's view that they are almost certainly of Archæan age. Without entering into details of correlation it may be stated that the Charnwood Rocks here are theoretically paralleled with the Lower Longmyndian and its volcanic equivalents, and the Caldecote Rocks with the Upper Longmyndian and Uriconian.

(1) *Malvern and Abberley Hills*.—The ancient rocks forming the core of the Malvern Hills have been so frequently described by geologists that they call merely for a brief notice in this place. They occupy a very narrow strip of country about eight miles in length, and less than half a mile in breadth; but, owing to their highly resistant nature, they stand boldly out as a highly picturesque, wedge-like, mountain ridge which rises to a height of from 500 to 1,000 ft. above the Severn plain at its eastern base, and culminates at a height of about 1,395 ft. in the point known as the Worcestershire Beacon, near the northern extremity of the range.

The main body of rock of which the core of the Malvern Hills is composed is crystalline, and locally gneissic and schistose. It was originally described by Prof. Phillips as a "syenite, associated with beds of a syenitic composition, but of bedded and even 'gneissic' structure," and he showed how it was pierced by numberless dykes, both of acid and of basic types. It is covered unconformably in the neighbourhood of Raggedstone Hill to the south-east by the basal bed of the Hollybush Sandstone (Lower Cambrian). It was consequently claimed by Dr. Holl (as early as 1865) to be of Laurentian or Archæan age. On the western flanks of the range, at the locality of Herefordshire Beacon, there occurs a small area of volcanic rocks, mainly pyroclastic, which were claimed by Dr. Callaway, in 1880—on the ground of their lithological characters and stratigraphical position—as appertaining to his volcanic series of the Uriconian of Shropshire, a view which has subsequently been very generally accepted.

Structurally, these Archæan Rocks of the Malvern range form the crest of a long anticline, which throws off a band of Silurian strata along its western margin, but is limited by a strong fault to the east, by which the Triassic strata of the Severn valley are brought into juxtaposition with the crystalline rocks of the range. At the North Hill this north and south fault makes a sudden swerve, and the crystalline rocks suddenly disappear. The fault, however, is continued with an undulating course, far to the northward across the lower ground, well into the district of the Abberley Hills. Side by side with it, immediately to the west, is also continued the anticlinal form. For the greater part of its course between the Malvern and Abberley Hills the crest of the anticline is constituted of Silurian strata; but, at the

locality of Berrow Hill, syenitic rock again appears at the surface, but only for a very short distance ; it is here accompanied by quartzite.* There can be little doubt, however, that crystalline Archæan rocks, with similar characters to those of the Malvern mass, are continued uninterruptedly below the Silurian along this anticlinal form, from the northend of the Malverns into the Abberley Hills. This may not only be inferred from the anticlinal disposition of the Silurian rocks themselves, but it is rendered practically certain by the fact that the Llandovery beds along this line are largely made up of materials clearly derived from rocks of the Malvern type.

(2) *The Wrekin Hills*.—The Archæan rocks of the Wrekin Hills rise out unconformably from below the local Cambrian Quartzite in a long linear ridge formed of the four elevations known as the *Ercal*, *Lawrence Hill*, the *Wrekin*, and *Primrose Hill* ; and also in a lower but broader ridge to the north-west, namely, that of *Wrockwardine*, which forms a well-marked inlier in the Triassic ground. In all these localities the Archæan rocks, which here constitute the typical Uriconian System of Dr. Callaway, are clearly of volcanic origin. They consist of thick rhyolitic lavas, volcanic breccias, and rhyolitic, andesitic, and basic tuffs ; with intrusions of granitoid rock, felsites, and basalts. Some of the bedded rocks are conglomeratic, and there are occasional volcanic gritstones and shales. Some of the basic rocks of these hills, and of the neighbouring “Uriconian” district of the Caradoc and Lawley ranges to the south-west, are newer than the rhyolitic and andesitic groups, but although later in date than the main masses of the Uriconian volcanic rocks, they appear to be of an age long anterior to the overlying Cambrian.

(3) *Inlier of Barnt Green*.—The “Basement Rocks” of this locality occupy a small area, ranging north-west and south-east, about half a mile in length by less than a quarter of a mile in breadth, and lying a short distance northward of the railway junction of Barnt Green. The area is somewhat elevated above the surrounding country, and constitutes the terminal section of the long, wedge-like range of the Lower Lickey Hills. To the north of this section the range is much higher, and is formed mainly by the outcrop of the Cambrian Quartzite. To the south of the section the ridge disappears as such, its ancient rocks diving beneath the Triassic strata of the Midland plain. The inlier is bounded to the eastward by Triassic rocks, and to the westward by steeply dipping red sandstone strata, which are usually classed as Permian.

The rocks which floor this Barnt Green inlier are very indifferently exposed. The most intelligible sections are seen along the course of the small Barnt Green Brook, within the private grounds of Barnt Green House. Here a series of stratified rocks is met

* Coles, *Geol. Mag.*, Dec. 4, vol. v, 1898, p. 304.

with, dipping at various angles, but with a persistent north-west to south-east strike, agreeing with that of the main axis of the Lickey Hills. The commonest rocks are flaggy and shaly beds of green, grey and purple tints, but purple and chocolate coloured gritty sandstones also occur. The materials of which the finer-grained beds are composed are distinctly pyroclastic in origin, and occasional coarser layers are met with, containing chips and fragments of felsite and abundant crystals of felspar, chiefly orthoclase. These rocks, which are shown in various small sections, are always much shattered and broken, and usually more or less veined with calcite, and more rarely quartz, but the bedding as a rule is very distinct. Some of the layers may be perhaps best classed as tuffs, and others as volcanic grits. They appear to have been all deposited in water, but the general absence of rounded grains of quartz, and the conspicuous angularity of the particles of volcanic matter, are suggestive of their deposition during a time of contemporaneous igneous action rather than of their secondary derivation as the worn detritus of pyroclastic rocks already consolidated. Some thin zones of compact pink

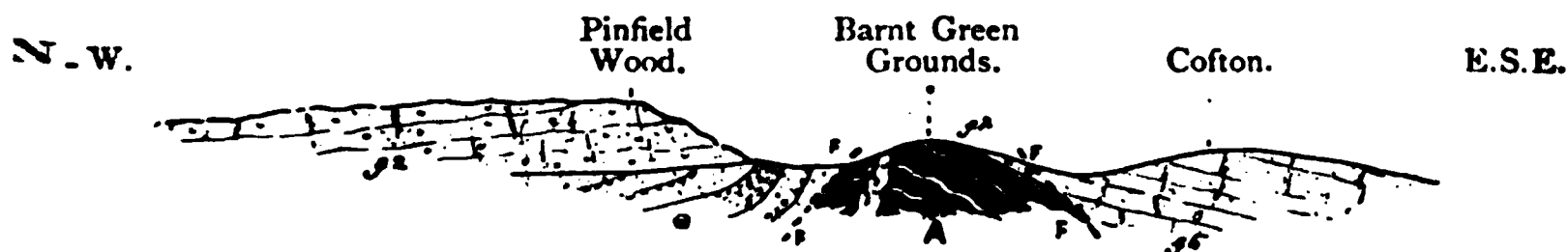


Fig. 5.—SECTION ACROSS THE SOUTHERN END OF THE LICKEY HILLS.—*C. Lapworth.*

Keuper Sandstone. *f*². Bunter Pebble Beds. *e*. Permian Marls and Sandstones.
A. Barnt Green Rocks pierced by Diorite. F. F. Faults.

felsitic rocks occur in the series, which may be intrusive, but are possibly formed of the more finely-grained and silicified volcanic dust. Remnants of a dyke of vesicular basic rock occur at the eastern extremity of the section.

A shorter section of similar stratified rocks, showing also one of the pink felsitic bands, occurs at the head of a small rill-course which furrows the eastern side of the inlier about midway along its length.

Exposed sections of the stratified deposits are not known to occur elsewhere within the inlier; but the surface of the ground is scattered over with a kind of loose breccia, formed by the *débris* of these rocks. This is very well shown along the hedgerows east of the main crest. Upon the western half of the area the rock *débris* occurring loose upon the surface, or ploughed up in the fields is somewhat different, and the rocks here may perhaps belong to a later series. South-west of the central parts of the ground the *débris* consists largely of a highly quartzose gritstone, almost a quartzite, containing chips and dust of felspathic matter. Toward the north-west, the plough turns up abundant fragments

of sandy nodular shales, locally black in colour, and crowded with mica flakes, as first discovered by Mr. Gibson.

A broad dyke of vesicular diorite runs down the centre of the western half of the area, almost parallel with the south-western boundary, and is well exposed in several points along its length. Similar diorite rocks occur also beneath the hedgerows on the south side of the roadway crossing the ridge at Kendal End.

Since their original discovery in 1882, the bedded rocks of Barnt Green have been paralleled by Midland geologists with the Caldecote Volcanic Series of the Nuneaton region, with which they agree in the general pyroclastic nature, in the presence of basic intrusions and in their probable immediate infraposition to the Cambrian Quartzite of the Midlands. The diorite dykes of the Barnt Green area also apparently agree lithologically with those of the Nuneaton region; but while these diorites pierce some of the strata at present united with the pyroclastic rocks of Barnt Green, they are as yet unknown in the Caldecote Series of the Nuneaton area, where they are met with for the first time in the basement beds of the overlying Hartshill Quartzite.

The Barnt Green area of basement rocks is cut off from the area of Lickey Quartzite to the northward by a transverse fault (or faults) which crosses the ridge at the locality of Kendal End. We are, therefore, deprived of stratigraphical evidence of the actual infraposition of these Barnt Green rocks to the local Cambrian Quartzite. A little northward of the Barnt Green area, certain of these Cambrian beds are well shown. They are formed of thin quartzites with many interbedded shales. Both by their position and their lithological characters, these beds appear to answer to the lower zones of the Nuneaton Quartzite, and they not only contain many thin ash-y layers suggestive of extension of the Barnt Green conditions into the Quartzite period, but some of the softer sandy beds, containing much volcanic material met with here and there in the series, are very similar to some of those occurring in the Barnt Green inlier itself.

(4) *Caldecote District*.—To the east of the Cambrian district of Nuneaton there occurs an area of pyroclastic rocks which is nearly two miles in length, but is less than a quarter of a mile in breadth. The rocks displayed in this area consist of sheets of volcanic breccia, tuffs, and volcanic grits, with a few intrusive dykes of basic rock. The dominant rocks are crowded with scattered crystals and grains of felspar and quartz, and have at first sight the appearance of quartz-felsite. Both orthoclase and plagioclase occur. The quartz grains are sometimes rounded, sometimes angular, and here and there the rocks show conspicuous compact green and black patches. The ground-mass or matrix appears to be of the same general composition as the coarser and more evidently crystalline material which it encloses. A second and very common type is

stratified breccia, or agglomerate, with a purple and greenish base crowded with pink chips and fragments of felspathic material. From these two types there are gradations, on the one hand, into crystal-tuffs almost inseparable from ordinary quartz-felsites; and, on the other hand, through fine tuffs almost inseparable from ordinary volcanic grits to beautifully laminated deposits formed of microscopic and sub-microscopic grains.

Some of the coarsest breccias of the Caldecote Rocks are met with in the sides of a disused road near the Anchor Inn, and are apparently the lowest volcanic rocks exposed to view. The more compact tuffs with the aspect of brecciated quartz-felsites are best shown in Mr. Abel's Long Quarry immediately south of Hartshill Grange, where they are succeeded by the basement beds of the Cambrian (Hartshill) Quartzite. These felsitic tuffs have here weathered into gigantic, ball-like masses, and form a most remarkable and conspicuous group. Fragments of the same type of tuff can be collected along the same line of strike in the slopes between the White House and the Hill House; and the rock itself can again be seen *in situ* in an old quarry on Caldecote Hill, the "*Blue Hole*," where it is pierced and partly overlain by a mass of basic rock.

In the road immediately north of Hartshill Grange, green volcanic tuffs and grits occur, somewhat similar in character to the quartz-felsite-looking breccias. They are, however, rudely stratified and show occasional rounded grains.

In the sides of an old tunnel within a few yards of Caldecote Hill House there is an exposure of remarkably fine-grained tuffs. Some are beautifully laminated in parallel closely-set bands of different tints, while others are more compact and break with a conchoidal fracture; but even these latter show distinct evidence of bedding in their occasional layers of coarser volcanic material, along which they may be easily split into parallel-sided slabs.

In the old quarry at Caldecote Hill, as already mentioned, a sheet of basic rock partly intrudes upon, and partly overlies, the Caldecote ashes. A vertical dyke of similar basic rock also cuts the Caldecote rock in the exposure at Mr. Abel's quarry near Hartshill Grange.

The Caldecote pyroclastic series is followed at once to the north-westward by the Hartshill Quartzite, which forms the accepted base of the Cambrian system in the Nuneaton district. The strike and dip of the laminated tuffs of the Caldecote Rocks are well shown in the sides of the tunnel upon the flanks of Caldecote Hill, and both appear to agree with those of the beds of the quartzite to the north-west. The great contrast, however, between the lithological characters of the Cambrian Quartzite and those of the underlying series of Caldecote Volcanic rocks is very striking, and is suggestive of the lapse of a long interval of time

between them. The basement Quartzite beds generally rest upon an irregular band of rotted fragments of the underlying Caldecote Rocks; and at the entrance of Mr. Boon's quarry, the Quartzite itself, for some distance upwards from its base, contains large rounded blocks of Caldecote volcanic rocks, while the matrix is mainly composed of the rounded wash of similar material. A most interesting mass of this block-bearing group has been recently laid bare in the Quarry. Everywhere to the north-east of this point, where the lower beds of the Cambrian Quartzite are exposed, they are purple in colour, more or less conglomeratic, and contain pebbles and grains of volcanic material. There are indications, however, that volcanic conditions had not wholly ceased in Cambrian time, for even among those zones where the Quartzite is most typical, occasional layers are intercalated which are seen to be largely made up of volcanic matter, and to contain chips and

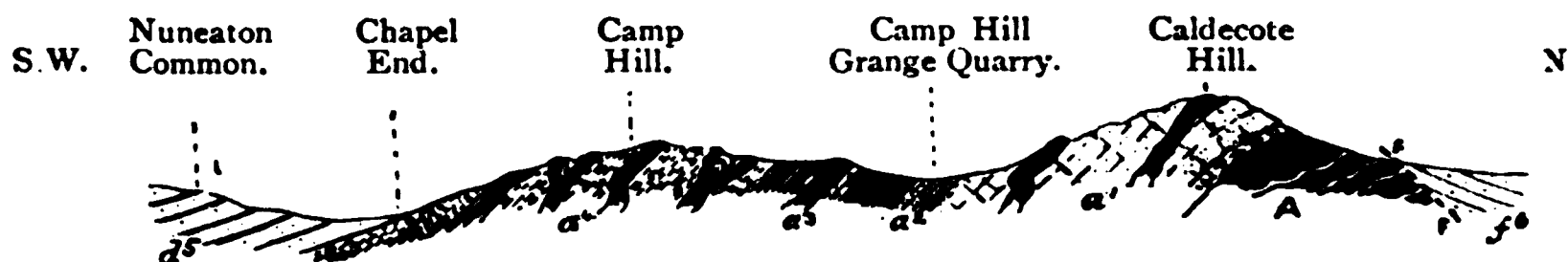


FIG. 6.—SECTION ACROSS THE CENTRAL PART OF THE NUNEATON RIDGE.—*C. Lapworth.*

- | | |
|--|---|
| <i>f</i> ⁶ . Keuper Marls. | <i>a</i> ² . Hyolithus Beds. |
| <i>d</i> ⁵ . Coal-measures. | <i>a</i> ¹ . Cambrian Quartzite. |
| <i>a</i> ⁴ . Black Stockingford (Oldbury) Shales. | <i>A</i> . Caldecote Volcanic Rocks. |
| <i>a</i> ³ . Purple Stockingford (Purley) Shales. | Black rocks—Diorite Dykes. F. F. Faults. |

rounded blocks (often of large size) of volcanic rocks, more or less of the ordinary Caldecote type. Some of these volcanic pebbles, however, are more basic in character than the generality of the Caldecote rocks; they may perhaps be due to the erosion of volcanic rocks of later date than those of the typical Caldecote area, belonging to a period here represented only by the intrusive basic dykes, which may possibly be paralleled with the similar later basic series of the Wrekin and Caradoc Hills.

(5) *Charnwood Forest* (contributed by W. W. WATTS).—In Charnwood Forest there occurs a considerable area of pre-Cambrian rocks, the most easterly exposure at present known in Britain. The ancient massif is almost submerged beneath a mantle of Trias, only the higher peaks emerging, while Carboniferous rocks, the magnesiferous limestones of Grace Dieu, are only known to touch it at the north-west corner.

The rocks are mainly of volcanic origin, and include coarse breccias and agglomerates, conglomerates, tuffs, and ashes, at times so fine-grained as to pass into hornstones and slates. The

structure of the area is an elliptical dome elongated from N.W. to S.E. ; only the south-eastern half is, however, exposed.

The rocks admit of subdivision, according to lithological character, into three broad Series, neither base nor summit of the formation being visible. The Series may be again subdivided as shown in descending order below :—

Swithland and Groby Slates.	}	The Brand Series.
Conglomerate and Quartzite.		
Purple and Green Beds.		
The Olive Hornstones of Bradgate.	}	The Maplewell Series.
The Woodhouse Beds.		
The Slate-Agglomerate of Roecliffe.		
The Hornstones of Beacon Hill.		
Felsitic Agglomerate.	}	The Blackbrook Series.
Rocks of Blackbrook.		

The succession may be best studied on the eastern side of the Forest, where the sequence is plainer and the disturbance less prominent than on the western side.

The oldest rocks crop out at intervals along the core of the arch, chiefly about the Black Brook. They consist of pale, sometimes purplish or greenish and banded, grits and hornstones ; frequently they have the macroscopic aspect of felsites and quartzites, and in places they are fine-grained enough to be used for honestones.

The Maplewell Series is characterised by its dominant apple-green colour, but many of the fine tuffs weather white. Coarser ashes are of frequent occurrence, and two bands of breccia, discovered and in part mapped by Professor Bonney and Mr. Hill, may be traced for considerable distances round the Forest. The lower of these is a felsitic agglomerate seen near Whittle Hill and Black Hill, and in a very faulted condition in Benscliffe Wood ; the higher is the Slate-agglomerate which occurs at Woodhouse Eaves, Roecliffe, Bradgate, and Markfield. Between the two agglomerates there occurs a very well-marked group of fine, banded, green hornstones, well seen on Beacon Hill. A marked feature of the Slate-agglomerate is the occurrence of huge masses of green and purple slate which are found in it. Above this agglomerate coarser beds become rather more frequent, and at the top of the series there is a set of olive hornstones (almost without coarser bands) which is only visible in Bradgate Park.

The highest Series, named after the picturesque grounds of the Brand, begins with a conglomerate containing rounded pebbles of felsite, slate, quartz, and quartzite. This graduates upwards into a reddish sandstone, which locally passes into a quartzite, red or black in colour, and with a bright, lustrous fracture. These rocks are to be seen at Woodhouse Eaves, the Brand, and

Bradgate. Above them there is a band of purple slate worked at Woodhouse Eaves and elsewhere, and that is followed by a curious rough, black, ashy grit which can be recognised in many places. In some slaty beds associated with the quartzite, Prof. Lapworth and Mr. Rhodes have found what appear to be worm-casts. The slates, purple and green in colour, formerly so much worked at Swithland and Groby, succeed and appear to be repeated two or three times by folds.

The succession thus far sketched out may be followed from Shepshed by Nanpanton to Woodhouse Eaves and the Beacon Hill, and thence to Bradgate and Markfield. Here exposures become fewer and more difficult to correlate; until, on reaching the north-west corner of the district, entirely different rock-types are found which it is almost impossible to parallel with the rest of the area. Messrs. Bonney and Hill incline to the belief that these rocks are of the same age as the Maplewell Series, but differ from them in having been deposited nearer to the volcanic vent. This correlation appears to be upheld by the presence of a felsitic agglomerate at the base of the sequence and a slate agglomerate at its summit. Between these two horizons the ground from Grace Dieu to Bardon, and from Peldar to Timberwood Hill and High Sharpley, is occupied by massive agglomerates and by nodular and other porphyroids. Both these rocks occur in irregular masses, and only very rarely in traceable beds. Indeed, the latter rocks can be best explained by supposing them to be intrusive, a conclusion warranted by a junction between them and the agglomerates at Bardon Hill.

The principal axis of folding in the region extends from N.W. to S.E., and the movement which has folded the rocks into an anticline along this line has also produced a set of faults parallel to it; while the strike of the cleavage, unless diverted by local circumstances, follows the same law.

The earliest intrusive rocks in the district appear to be the porphyroids of Peldar, Sharpley, and Bardon. Following this comes the intrusion of the augitic syenite which covers great areas in Bradgate, Groby, and Markfield; a similar rock crops out from under the Trias at Croft and Enderby to the S.W. of the Forest. Although there is no absolute proof of its later date, the hornblendic granite of Mount Sorrel and Brazil Wood seems to be the next rock intruded, and in the quarries of this again there are dykes of altered dolerites later still in age.

The age of the bedded rocks of Charnwood Forest cannot be ascertained by any evidence from superposition, so that structure and petrology are the only guides. The rocks certainly are pre-Carboniferous. They have nothing in common with the Devonian, Silurian, or Ordovician Rocks. They are altogether unlike the Cambrian rocks of Nuneaton, and have been much more affected by earth movement. They present little corre-

spondence with the Uriconian Rocks of Caldecote, the Lickey, and the Wrekin. Even the intrusive rocks, like the Peldar porphyroid and the syenite, are quite unlike the rocks which pierce the Cambrian and Uriconian Rocks of the Midlands. It is therefore likely that they belong to a pre-Cambrian System distinct from, and possibly older than, the Uriconian rocks. If this is the case, it may be well to designate the whole succession for the present by a distinctive name such as "*The Charnian Rocks.*" (See pp. 326, 327.)

Cambrian System.

Strata belonging to the Cambrian System are now known to be well developed at several localities within the limits of the Birmingham District. Abundant evidences have also been accumulated of late years which render it practically certain that strata representative of the entire Cambrian System were deposited over the greater part, if not over the whole of the Midland region. The lithological and the palæontological facies of these Midland strata are, however, very unlike those of the typical Cambrian region of North-west Wales, and approximate more closely to those of the Cambrian of Scotland, and those of the continent of Europe.

The Cambrian rocks of the Midlands appear at the surface in four distinct and isolated areas, viz., those of (1) the Wrekin Hills, (2) South-west Malvern, (3) Nuneaton, and (4) the Lower Lickey Hills.

Owing in part to the obscure stratigraphical relationships of the Cambrian rocks occurring in these districts, and in part to the great rarity of fossils within them, their true systematic position remained long unsuspected. The Cambrian strata of the Wrekin and Malvern areas were formerly classed with the Ordovician; those of the Lickey Hills with the Silurian; and those of Nuneaton with the Coal Measures and the Millstone Grit. The demonstration of the true geological age of these Midland Cambrian deposits in general, and the correlation of the formations here represented with the Cambrian formations of other districts, has not only been a work of slow accomplishment, but cannot, even yet, be said to be fairly complete.

In the typical Merioneth region of North-west Wales the strata usually assigned to the Cambrian system are known to be of enormous thickness, and to fall naturally into two lithological groups. The lower group is essentially *arenaceous*; it is formed of the Harlech grits and flags, is more than a mile in vertical extent, but is *barren* of all fossils except a few worm-burrows. The upper group is essentially *argillaceous*; it is a succession of flagstones and shales, is of corresponding thickness, but is more or less *fossiliferous* throughout. This upper group has

long been separated into three palæontological divisions as the (a) *Menevian*—characterised by the presence of *Paradoxides*; (b) the *Lingula Flags*—marked by forms of *Olenus* and by the presence of the genus *Dictyonema* in its highest beds; and (c) the *Tremadoc Slates*—containing an admixture of Cambrian and Ordovician organic types, and consequently referred by many to the Ordovician System.

In the Birmingham District (within which, for the moment, we may include not only the Wrekin area, but also its south-westerly extension, the Caradoc region of Central Shropshire) we also find the Cambrian System made up of two distinct lithological members: namely a Lower arenaceous division and an Upper shaly division. The entire system, however, is here reduced to a thickness of about 2,000 ft. and the component formations bear, as a rule, but little resemblance lithologically to their N. Wales prototypes. In place of the single, monotonous Harlech series we have here a double formation; the lower division of which is composed of the siliceous *Wrekin Quartzite*, and the upper of the more or less volcanic *Hollybush (or Comley) Sandstone*, the two being locally divided from each other by thin calcareous zones (the *Comley Limestone*), often rich in fossils. Again, in place of the thick flaggy and carbonaceous Upper Cambrian of N. Wales we have in the Midlands and West of England, several formations—all composed of thin-bedded strata, only locally carbonaceous, more generally made up of exceedingly fine-grained material—often felspathic, and usually of bright tints of green or reddish purple.

Further, the "*Olenellus*-zone," so conspicuous abroad, but as yet unknown in the typical Cambrian strata of N. Wales, occurs in the Shropshire area at the base of the Comley Sandstone; whereas, on the other hand, the Menevian strata, so remarkably conspicuous in the Welsh succession because of their characteristic forms of *Paradoxides*, are very indifferently represented in the Midland and W. of England districts. Only one member of the Lingula Flags of N. Wales seems to be represented both lithologically and palæontologically by a corresponding formation in the Midland succession: this is the Dolgelly formation of the Upper Lingula Flags, marked by the presence of *Sphærophthalmus* and *Ctenopyge* in its lowest beds, and *Dictyonema* in its highest zone. The succeeding Tremadoc formation is, however, well represented in the Wrekin area by the formation known as the Shineton Shales.

CAMBRIAN OF THE WREKIN AND CARADOC AREA.

Along a line drawn from north-east to south-west along the north-western border of the Birmingham District, the Cambrian strata are shown at several localities, between the town of Newport

and that of Church Stretton. The Cambrian strata occurring in the various Palæozoic exposures along this line are not only intimately related to those met with in the more central parts of the Birmingham District, but their rocks and fossils are of the utmost value in aiding us in paralleling the more truly Midland deposits with those of other regions.

(1) *The Wrekin Quartzite*.—This Quartzite—which varies from 100 to 200 ft. in thickness at the Wrekin to less than half that thickness in the Caradoc areas—rests unconformably upon the Uriconian Volcanic rocks both at the Wrekin and upon Caer Caradoc; and its basement bed contains rounded pebbles of rhyolite and other Uriconian detritus. No fossils are known in it except a few worm-burrows.

(2) *The Comley (or Hollybush) Sandstone*. — The Wrekin Quartzite is succeeded in the areas of the Wrekin, Caradoc and Sharpstones by a series of sandy beds, which are in some localities almost as siliceous as those of the underlying Quartzite, but more generally and typically are so rich in basic material as to become of a dark green colour; they are also marked by the frequent presence of glauconite. At the base, the Hollybush group is somewhat shaly and becomes locally very calcareous. In the neighbourhood of Neves Castle, these basement beds include a well marked limestone band, in the highest layers of which (and in certain overlying gritty beds) occur examples of *Paradoxides*. Upon about the same horizon at Comley—near Lebotwood, the limestone becomes purer and of greater thickness. Its lower beds there afford examples of *Olenellus* (*O. callavei*, etc.), *Agraulos*, *Stenotheca*, *Kutorgina cingulata*, etc.; and its highest layers fragments of *Paradoxides* (*P. groomii*, etc.).

At Lilleshall, six miles to the N.E. of the Wrekin, the Hollybush Sandstone covers a fairly large area. It is here faulted against the Uriconian Series and is overlain by the basement beds of the Carboniferous Limestone.

In the Wrekin District the Comley Sandstone is followed at once by the argillaceous series known as the *Shinerton Shales*. As a whole, the fauna of these shales is distinctly that characteristic of the Tremadoc slates of North Wales. Forms of *Bryograptus* occur in the middle beds; and in the highest beds, many genera and species of the Ordovician family of the *Asaphidæ*, in association with *Olenidæ* and other Cambrian forms. No trace of the *Lingula* Flags has yet been detected in this Wrekin region, unless they are represented in part by certain shales in the neighbourhood of Caer Caradoc, which apparently lie at the base of the Shinerton Series, and afford *Dictyonema sociale*.

At Maddox Hill, near the Wrekin, the Shinerton Shales are pierced by a sill of diorite, which has altered the Cambrian beds into which it has been intruded, and is overlain unconformably by unaltered beds belonging to the Carboniferous.

CAMBRIAN OF THE MALVERN HILLS.

The Cambrian rocks of the Malvern Hills occur near the S.W. extremity of the range, in the neighbourhood of Midsummer Hill and Key's End Hill, and occupy a superficial area of about three square miles. They repose unconformably upon the crystalline series of the hills to the E., and are covered unconformably to the W. by Silurian strata of Upper Llandovery age.

There is here no trace of the basement Quartzite of the Wrekin (a diminutive representative of which, however, has been met with at two localities between the Malvern and Abberley Hills), but the Lower division of the Malvern Cambrian is formed by the "*Hollybush Sandstone*," which attains a thickness of about 500 ft., and is a light green, flaggy, micaceous, and gritty rock containing much volcanic matter. A few of the layers near its base are somewhat calcareous, and yield *Kutorgina cingulata*, *Obolella salteri*, *Linnarssonia sagittalis*, and a form of *Hyolithus*. The actual basement layers are conglomeratic, and contain pebbles of the underlying crystalline rocks.

The Upper division of the Malvern Cambrian consists of a thickness of about 1,000 ft. of shales (the *Malvern Shales*). The lower half of this division is formed of the well-known Malvern Black Shales. These afford *Peltura scarabæoides*, *Sphærophthalmus alatus*, *Agnostus pisiformis*, *A. trisectus*, *Ctenopyge pecten*, etc., characteristic fossils of the Lower Dolgelly Beds of North Wales. The upper half of the division consists of Grey Shales, and affords the *Dictyonema sociale* of the Upper Dolgelly beds, and also *Asaphus* (*Symphysurus*) *croftii* and *Conophrys* (*Shumardia*) *salopiensis*, which are also known in the Shineton Shales of Shropshire (Callaway).

The Hollybush Sandstone and the overlying shaly beds contain numerous intercalated igneous rocks, some of which have been asserted to be of the age of the enveloping strata, but the majority are certainly intrusive.

CAMBRIAN OF THE NUNEATON DISTRICT.

In the neighbourhood of Nuneaton, in E. Warwickshire, there occurs a remarkable area of Cambrian rocks. This is bounded to the eastward by the Keuper marls of Central Leicestershire and is followed to the westward by the unconformably overlying Carboniferous strata of the E. Warwick coalfield.

The Cambrian strata of this area were formerly mapped as altered Millstone Grit and Carboniferous Shales, but not only have the strata been demonstrated of late years to be of Cambrian age by the discovery of typical Cambrian fossils within them, but it now appears exceedingly probable that the whole of the Cambrian system is represented here in an attenuated form.

This Cambrian area, which is about 9 miles in length with a maximum breadth of about 1 mile, ranges in a N.W. and S.E. direction from a point near Atherstone through the country a little to the E. of Nuneaton, almost to the village of Bedworth, about 5 miles N. of Coventry.

The Cambrian strata included in this inlier, like those found in the Wrekin and Malvern areas already described, fall into two main lithological divisions; a lower division, composed of arenaceous rocks (*The Hartshill Quartzite*), and an upper division formed of shaly strata, from which arenaceous rocks are usually absent (*The Stockingford Shales*).

Sills and dykes of diorite abound in these Cambrian rocks, especially in the upper or shaly division.

The area occupied by these Cambrian rocks of Nuneaton rises to a higher elevation than the surrounding country, which is occupied by the Keuper and Carboniferous beds; and much of the Cambrian ground, especially that occupied by the shales and their intrusive dykes, is richly wooded and remarkably picturesque.

Hartshill Quartzite.—The lower division of the Cambrian of the Nuneaton area is constituted by the "*Hartshill Quartzite*," so called from the little village of Hartshill, which is built upon it at its N.W. extremity. The outcrop of the quartzite itself is about $2\frac{1}{2}$ miles long, with a width of about one-third of a mile, and the collective thickness of the formation cannot be much less than 600 ft. The dip of the beds increases from about 25 degrees on the E. to 40 or 50 on the W. Along its eastern margin, where it reposes upon the pre-Cambrian Caldecote Volcanic Group already described, the Quartzite forms a steep scarp overlooking the plain of Central Leicestershire and the little valley of the Anker. Its middle beds form an almost level plateau, with a faintly marked central ridge. To the north-westward the ground declines gradually, and the highest bed of the Quartzite formation is here succeeded by the basement beds of the Stockingford Shales.

The main mass of the rocks which constitute the *Hartshill Quartzite* are bedded sandstones, usually of a pale pinkish colour. The grains of sand are set in a cement of quartz, forming a highly indurated rock, which, where not jointed, breaks with a sharp conchoidal fracture. Grains and particles of ashy matter occur in some of the beds, and a few of the bands are distinctly conglomeratic. The individual beds vary in thickness from 2-3 in. up to 4-5 ft. In the lower zones of the Quartzite the beds are softer and less siliceous than elsewhere; in the highest zones they become remarkably false-bedded. The Quartzite strata are frequently interrupted by bands and wayboards of purple and grey shales. These are most abundant in the lower third of the formation, where they often alternate layer

by layer with the quartzite beds. Sometimes, however, they group themselves into thick bands, the intervening quartzite strata being almost destitute of shaly seams.

Three of these thicker shale bands are especially conspicuous. Two of them occur almost in association at about a fourth of the height of the Hartshill Quartzite, and a third band is met with a short distance below the summit of the formation. The presence of these thicker shale bands allows us to separate the Hartshill Quartzite roughly into three divisions. That portion which intervenes between the base of the formation and the summit of the double shale band will here be referred to as the *Lower (or Park Hill) Quartzite*; that between the top of the Lower Quartzite and base of the third shale band as the *Middle (or Tuttle Hill) Quartzite*; and that between the base of the third shale zone and the summit of the formation as the *Upper (or Camp Hill) Quartzite*.

No fossils (with the exception of worm-burrows) have as yet been detected in the Lower and Middle divisions of the Hartshill quartzite, but the shales and limestones occurring in the Upper or Camp Hill division have afforded many organic remains.

Lower Quartzite (Park Hill Quartzite).—The strata forming the Lowest division of the Hartshill quartzite are admirably exposed in a long line of deep quarries, cutting the eastern scarp and running back to the roadway which practically follows the line of the central ridge. These quarries supply much of the road metal of the neighbouring districts of the Midlands, the rock being much used because of its great hardness and good weathering qualities.

The basement layers of the Lower Quartzite which follow at once upon the Caldecote Volcanic Series are very rarely exposed, and the actual place of contact is best seen in the cutting at the entrance to Mr. Abel's new quarry near Hartshill Grange. Here a deep and narrow excavation has been made through the Caldecote Rocks and the basement beds of the Quartzite, in order to reach the more compact and profitable quartzite bands higher up in the Lower Quartzite Series. In the cliff-like walls of this cutting, the Caldecote tuffs rise in a low anticlinal form, and are visibly overlain to the westwards by the basement bands of the quartzite, which shade almost insensibly upwards into the main mass of the Lower Quartzite which is excavated in the quarry beyond. Between the rocks which unequivocally appertain to the underlying pyroclastic Caldecote Series, and those which as undoubtedly form a constituent part of the overlying Hartshill Quartzite, only a few feet of rocks of a dubious character intervene. These are composed, in the main, of material of the same general type as that of the Caldecote Rocks, but are intermixed with soft conglomeratic grits and lenticular masses of shale. This intermediate series is stained of a bright reddish-violet colour, and may, possibly, represent



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FIG. 1.—QUARRY IN CAMBRIAN QUARTZITE, NEAR HARTSHILL.
(From a Photograph by Mr. W. Jerome Harrison.)



FIG. 2.—DYKE OF DIORITE IN HARTSHILL QUARTZITE. MR. TRYE'S QUARRY.
(From a Photograph by Prof. Watts.)

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the products of degradation of the underlying Caldecote Series. The peculiar basal deposits shown at Mr. Boon's quarry have already been described (pp. 331, 332).

In the quarries which intervene between these two localities there are several exposures of certain sandy and conglomeratic strata which succeed the actual basal layers, and form locally an upper part of the basement zone. They are usually purple in colour, contain a large proportion of ashy material in their matrix, and show occasional seams of pebbly rock.

The beds of the basement zone—which are collectively only a few yards in thickness—are of little economic value, but the strata which follow upon them, and form the main mass of the Lower Hartshill Quartzite, are, on the other hand, at present by far the most important beds in the entire formation from the economic point of view. They are now being worked in all the long line of quarries overlooking the canal, from Nuneaton to Hartshill Wharf. The majority of the strata are compact quartzites, which vary from 6 inches to 4 feet in thickness. In the lower half of the division the quartzites are thin-bedded and alternate with grey or purple micaceous shales; in the upper half the quartzites become more massive, and the shales group themselves into thick bands, some of which, as already mentioned, can be followed through the entire line of quarries for a distance of more than two miles.

Here and there among the more thinly bedded quartzites occur bands containing ashy material, similar to that of the matrix of the beds of the basement zone. Occasionally some of these coarser beds become conglomeratic, containing scattered pebbles or rounded masses of igneous rock (often andesitic or basic), together with pebbles of grey volcanic flagstones, not unlike some of the rocks of the Charnian Series. An excellent example of this conglomerate occurs in Messrs. Trye's quarry at the junction of the Anchor and Hartshill Roads.

Middle Quartzite (Tuttle Hill Quartzite).—The strata which belong to the Middle division of the Hartshill Quartzite are being worked in very few localities. Only two quarries are at present in operation in this division—namely, one at Tuttle Hill, opposite the Midland Railway Station, and another at the junction of the roads near Caldecote Windmill. Both afford good sections, as also do several disused quarries along the western side of the roadway running from the Windmill to Hartshill. The quartzites of this Middle group are very similar to those of the Lower division; but the shaly bands are thin and infrequent.

The strata of both the Lower and Middle Quartzite are invaded by dykes and sills of diorite. As a rule the larger intrusive sheets run parallel with the strike of the beds; but the smaller ones can occasionally be seen to cross from one bed to another. The largest of these dykes, which is 40 ft. to 50 ft. in thickness, is

shown in the Midland quarry, and in all probability runs through the whole length of the Cambrian country. These diorite dykes are, perhaps, most abundant in the lower layers of the quartzite, those in the Hartshill Grange quarry being riddled with several which vary from about 2 ft. to 5 ft. in thickness, and other dykes are met with in the zones above and below the shale bands. None of these dioritic rocks have yet been found to traverse the underlying rocks of the Caldecote series.

Upper Quartzite (Camp Hill Quartzite) or Hyolithus-Beds.—Near the summit of the Hartshill Quartzite the succession of arenaceous deposits is again broken by a shaly zone some 50 ft. in thickness. Like the shaly zones already mentioned, this band is both preceded and succeeded by strata which are

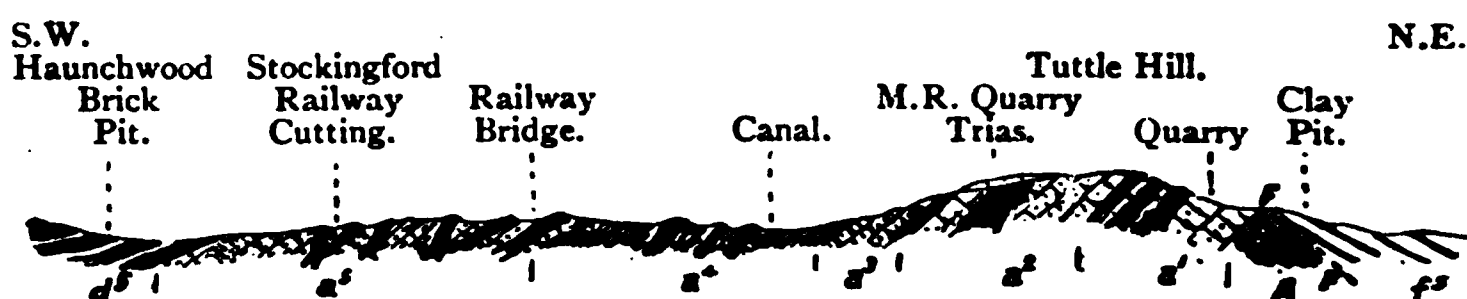


FIG. 7.—SECTION ACROSS STOCKINGFORD AND TUTTLE HILL, NUNEATON DISTRICT.—C. Lapworth.

Trias	<i>j</i> ⁵ . Keuper Sandstone.
Carboniferous	<i>d</i> ⁵ . Coal-measures.
U. Cambrian	<i>a</i> ⁵ . Oldbury Shales.
Stockingford Shales.	<i>a</i> ⁴ . Purley Shales.
L. Cambrian	<i>a</i> ³ . Camp Hill Quartzite.
Hartshill	<i>a</i> ² . Tuttle Hill Quartzite.
Quartzite	<i>a</i> ¹ . Park Hill Quartzite.
Pre-Cambrian	<i>A</i> . Caldecote Rocks.
<i>FF</i> . Faults.	Black Rocks—Dykes of Diorite.

best called quartzites; and, for convenience of lithological description, this shaly band and the quartzose strata above it are most naturally grouped together as constituting the Upper division of the Hartshill Quartzite itself. The only known exposure of this group is seen in the Camp Hill Grange quarry or cutting, belonging to Messrs. Trye, about midway along the S.W. edge of the main exposure of the Hartshill Quartzite.

As the shaly beds are approached the quartzite becomes thin-bedded, and is marked by the presence of abundant grains of glauconite. Sandy and marly shales, with much mica, then set in, alternating with the quartzose beds. They rapidly become more numerous, and at last preponderate, while the intervening arenaceous rocks grow soft and crumbly, and contain a notable quantity of carbonate of lime.

Where the rocks are most shaly, a conglomeratic band is met

with. This is from 6 in. to 9 in. thick, and is crowded with rounded pebbles of quartzite, vein quartz, and hardened shales. The matrix in which the pebbles lie is purplish red, but becomes occasionally quite black, and the pebbles themselves are coated by a black substance which stains the fingers. An analysis of the finer matrix, made by Dr. Warth, shows that it contains about 14 per cent. of phosphate of lime.

Above this conglomerate follow a few feet of purple shales, highly micaceous, and these are succeeded by 2 ft. of red-coloured *limestone*, well stratified. This limestone is remarkably hard and tough, and breaks with a conchoidal fracture. Some of its zones are very rich in fossils, especially in forms of *Hyolithus*.

The *Hyolithus*-bearing or Hyolite-Limestone is succeeded by a few inches of red shales, which, like the shales below and between the limestone bands, contain iron and manganese.

Finally, we have a mass of false-bedded quartzite or hard quartzose sandstone, about 50 ft. in thickness. This differs from the quartzite below the *Hyolithus* group in being more purple in colour and more distinctly false-bedded throughout. Grains and chips of red shaly matter, scattered chips and grains of volcanic material occur, together with abundant grains of glauconite.

This banded quartzite, which is somewhat calcareous at its summit, is followed immediately by the green and purple shales of a very fine texture, which form the base of the succeeding series known as the Stockingford Shales, the lowest bands of which here contain calcareous nodules. They are cut through by two dykes of diorite. Higher up they show the brilliantly red colour and impalpable texture so characteristic of the lower divisions of the Stockingford series.

The fossils of the Hyolite-Limestone and the associated shales (as provisionally determined by Miss E. M. R. Wood) include the following :

- Hyolithus* comp. *princeps*, Billings.
- „ „ *tenuistriata*, Linrs.
- „ „ *obscurus*, Holm.
- „ „ *lenticularis*, Holm.
- Orthotheca de geeri*, Holm. *O. johnstrupi*, Holm.
- O.* comp. *communis*, Billings, *O. corneolus* (?) Holm.
- O.* comp. *teretiusculus*, Linrs.
- Coleoloides typicalis*, Walcott.
- Stenotheca rugosa*, Walcott. *S. rugosa* var. *abrupta*.
- Kutorgina cingulata*, Bill.
- „ *labradorica*, Bill.
- Orthisina* comp. *transversa*, Walcott. *Scenella* sp.

The general facies of the curious fauna of this Hyolite-Limestone speaks strongly in favour of the view that it is of Lower Cambrian age, answering in part to the *Olenellus*-zone of

other regions. The Camp Hill species of *Hyolithus* are best compared with species occurring either in the *Olenellus*-zone of Sweden or of North America, and the *Coleoloides* is very similar to one found upon the *Olenellus* horizon in America. The forms of *Stenotheca* and of *Kutorgina* find their nearest allies in species occurring in the *Olenellus*-zone in America and in the *Paradoxides*-zones in Scandinavia.

The stratigraphical place of the Hyolite Limestone in the general sequence of the Nuneaton Cambrian also supports this view. It lies between the main Cambrian Quartzite of the district and a second arenaceous band, as the *Olenellus* and *Paradoxides*-Limestone of Shropshire lies upon the Wrekin Quartzite and is covered by the Hollybush Sandstone. The Trilobites of the Shropshire deposit are wanting from the Camp Hill Limestone, but the species of *Stenotheca* and *Kutorgina* appear to be common to both.

If this view of the geological age and stratigraphical place of the Hyolite Limestone band is well founded—the Camp Hill false-bedded or banded Quartzite answers to the Comley or Hollybush Sandstone of the Shropshire and Malvern successions. At first sight it would seem that the two had little or nothing in common lithologically; but on the one hand the green Hollybush Sandstone contains occasionally so much arenaceous matter as almost to deserve the name of quartzite; and on the other this Camp Hill Quartzite is marked by the presence of basic volcanic matter like that present in the Hollybush Sandstone, and like that formation is fairly rich in grains of glauconite.

Stockingford Shales.—Following immediately upon the Camp Hill Quartzite, and apparently coinciding precisely with it as regards its dip, we find a thick mass of shaly strata, namely, the Stockingford Shales. This name was first suggested by Mr. Jerome Harrison after the locality where these beds are well displayed.

These Stockingford Shales fill up the greater part of this Cambrian district. In the central parts of the inlier, between Chapel End and Nuneaton, their outcrop is about a quarter of a mile in width. To the N.W. and S.E., however, their breadth rapidly increases, and beyond the point where the Quartzite disappears north of Hartshill and south of Tuttle Hill, the Stockingford Shales occupy the entire diameter of the inlier.

To the south-westward the Stockingford Shales are followed unconformably by the basement beds of the Carboniferous of the E. Warwickshire Coalfield. An excellent section of the unconformity between the two systems is shown in Messrs. Trye's new railway cutting N. of Chapel End.

As we trace the base of the Carboniferous to the N.W. from Stockingford to Merevale, higher and higher bands of the Stockingford Shales rise out from below, until at Merevale Park and its neighbourhood the highest known strata of the Stockingford Shales, namely, the *Dictyonema* Beds, are laid bare, and the out—

crop of the formation is at its maximum width of a little more than a mile.

The Stockingford Shales consist throughout of fine-grained materials, forming thin-bedded shales or crumbly mudstones. The shales, where best developed, split into layers often as thin as a playing card, and the mudstones occur in thick bands, breaking up into shivery and wafer-like fragments. There are few or no well-marked sandy or gritty beds throughout the entire series, although strata of a more compact character occasionally occur. These, however, owe their hardness to the presence of calcareous matter or to the proximity of the injected igneous rocks.

The Stockingford Shales fall into three fairly well-marked lithological divisions, namely :

1. A *Lower Division*, formed of brightly-coloured purple mudstones and shales, approximating almost to scarlet, with occasional green and grey bands, more or less felspathic ;

2. A *Middle Division*, formed essentially of black shales, often highly carbonaceous and ferruginous ; the black shales being locally interrupted by bands of grey and green material ;

3. An *Upper Division*, formed of grey shales, apparently destitute of both the red and black bands, and somewhat thicker-bedded than the shales of the lower divisions.

Lower Stockingford Beds (Purley Shales). — The Lower Stockingford Shales or purple mudstones range from Wash Lane to the W. of Nuneaton, along the S.W. margin of the Quartzite, past Camp Hill and Hartshill, and are continued through Purley Park into the rolling grounds of the Outwoods as far as Atherstone. The dip varies from 30 degrees to 60 degrees, and the thickness of the zone may be set down as about 600 feet.

The beds belonging to this group are exposed in Atherstone Outwoods, Purley Park, and in the Midland Railway cutting near Nuneaton ; the best sections are those in Purley Park Lane. The majority of the beds are of a reddish purple colour, possibly due to the presence of manganese, which was formerly worked in this group. With the purple zones occur bands of pale-green shales, often weathering to a buff tint. The entire group has all the appearance of being largely formed of excessively fine-grained felspathic material, either contemporaneous volcanic dust, or the impalpable wash derived from an area of consolidated igneous rocks. Lithologically, this sub-formation bears a striking resemblance to the well-known Tarannon Shales of Wales. Near the summit of the sub-division dark grey bands begin to come in, with carbonaceous seams here and there, and the group passes insensibly into the succeeding sub-formation, in which the characteristic purple beds are wanting.

This purple and green group, which we may call the
AUGUST, 1898.]

Purley Shales, after the locality where they are best exhibited, has yielded as yet but few fossils. These fossils are usually confined to thin zones, and the main mass of the rock appears to be wholly barren. The best locality for fossils from this sub-formation is Purley Park Lane. The following include the forms which have been collected up to the present time.

Minute forms of *Lingula* or *Lingulella* occur, which call to mind the *Lingula* sp. of Linnarsson, figured by him from the *Paradoxides forchammeri* beds of Sweden. Some of the examples have been referred to *Lingulella ferruginea*, Salt., from the Menevian Beds of St. Davids, some to *Lingula pygmea*, from the Black shales (*Lingula* Flags) of Malvern, and others to *Lingulella lepis*, Salt., from the Up. *Lingula* Flags of Portmadoc. According to Mr. C. A. Matley, who has worked over the Brachiopoda, it is possible, however, that only one species (*Lingula* sp.) occurs here, together with a well marked and more pointed variety.

Associated with these is *Obolella* comp. *sagittalis*, Salt., which occurs in the Menevian, and in the Hollybush Sandstone of Malvern. *Acrothele granulata*, Linrs., of the Swedish *Paradoxides forchammeri* Beds, and *Acrothele* comp. *intermedia*, Linrs., of the *Conocoryphe exulans* Beds of Sweden have also been identified, together with a new form.

There is a new form of *Acrotreta*, according to Mr. Matley, allied to *A. sociale* v. Seebach and to *Obolella sabrinæ* of Callaway. We have also examples of a sponge allied to *Protospongia fenestrata*.

Only one fragment of a trilobite has been met with, which shows the pygidium and a few body segments. It is probably referable to *Conocoryphe*, and allied to *C. coronata*, Barr., and *C. exulans*, Linrs.

Middle Stockingford Bed. (Oldbury Shales).—These form the central or main division of the Stockingford Shale group, and are characterised by the abundance of black carbonaceous bands which they contain, associated, however, with many bands of grey and brown tints. The rocks, as a whole, are harder than those of the Lower Stockingford series and contain a much smaller proportion of felspathic matter.

The rocks are well exposed in the cutting of the Midland Railway at Stockingford, and in the London and North-Western Railway cutting at Chilvers Coton. Other sections occur along the banks of the canal near Griff, in the quarries and cuttings at Chapel End, in the quarry at Oldbury reservoir, in the woods near Mawbornes, and elsewhere.

Fossils are somewhat more common in this series than in the underlying division, but they are nowhere abundant. In what appear to be the lowest beds as shown near Chilvers Coton, there occur examples of an *Agnostus* of the type of *A. pisiformis*, Linrs. (apparently var. *sociale* of Tullberg). This has also been met with in

the Stockingford cutting and near Oldbury reservoir. Perhaps the commonest fossil in the lower parts of the band is a *Beyrichia*, apparently identical with *B. angelini*, Barr., a well-known Swedish form. With this occurs a species of *Lingula* or *Lingulella*, of the type of *L. lepis* and *L. sabrinæ*, together with a species of *Leperditia*. At a somewhat higher horizon the officers of the Geological Survey obtained many fragmentary examples of an Olenoid form, *Olenus* (?) *nuneatonensis*. Another form of *Agnostus*, apparently *A. cyclopyge*, Tullb., is met with in the middle beds of this group in the Stockingford cutting, etc. What appear to be the highest zones of this band occur in Mawborne Woods, and have yielded abundant fragments of forms which appear to belong to *Sphærophthalmus alatus*, Boeck, and *Ctenopyge* (compare *C. pecten*, Salter).

Upper Stockingford Beds (Merevale Shales).—These are known only in the extreme N.W. corner of the Cambrian inlier, in the neighbourhood of Merevale Abbey. They are marked by the presence of abundant examples of *Dictyonema sociale*, Salt. = *D. flabelliformis*, Eichwald, which were first detected here by the officers of the Geological Survey.

Few sections are exposed, the best being shown in an old quarry 200 yards W. of Merevale Abbey.

The strata consist of thin-bedded greenish-grey shales, which agree in their general characters with the similarly coloured shales that alternate with the black carbonaceous beds of the Middle or Oldbury division.

The following table shows the vertical distribution of the fossils already obtained from the Cambrian rocks of this Nuneaton inlier, together with that of their nearest allies or representatives occurring in other regions. It has been drawn up by Miss E. M. R. Wood, who has recently re-examined the Cambrian fossils from these Nuneaton Rocks, obtained by Midland geologists, and also (through the kindness of Sir A. Geikie) those in the collection of H.M. Geological Survey. Those marked (S) occur only in the Survey Collections; those marked (M) in the Collections of Midland Geologists; the remainder appear to be common to both. It is evident that the fossils of the Hyolite limestone at the base appear to have their nearest representatives in the *Olenellus* zone or Lowest Cambrian of Europe and America. Those of the Lower Stockingford Shales occur in the *Paradoxides* or Menevian zone; those of the Middle and Upper Stockingford Shales are found elsewhere in the upper division (or Dolgelly group) of the *Lingula* Flags. The Black Shales of the Middle Stockingford Division (or Oldbury Shale) may be confidently paralleled with the Lower Dolgelly Beds of North Wales and their equivalents the Black Shales of Malvern; and the Upper Stockingford Shales (Merevale Shales), with the succeeding Upper Dolgelly Division (*Dictyonema*-beds) of North

Nuneaton Localities.	Other British Localities.	Foreign Representatives and Localities.
Dictyonema Beds (Merevale Shales) <i>Dictyonema sociale</i> , Salt. ...	Merevale Abbey ...	Comp. <i>D. flabelliforme</i> , Eich. of Up. Cambrian, of Esthonia, Sweden, Norway; also <i>D. canadense</i> , N. America. —
<i>Hyolithus</i> , sp. (S.) ...	" " ...	—
Black Shale Group (Oldbury Shales) <i>Ctenopyge pecten</i> , Salt. ...	Mawbornes... ...	Zone of <i>Peltura scarabæoides</i> , Scania, 2 <i>d.</i>
<i>Sphærophthalmus alatus</i> , Boeck.	" ...	Zone of <i>Peltura scarabæoides</i> , Scania, 2 <i>d.</i>
<i>Olenus nuneatonensis</i> , Sharman (S.)	Stockingford Cutting, west end, Mid. Railway ...	—
<i>Olenus</i> , sp. comp. <i>salteri</i> , Call.	Mawbornes... ...	—
<i>Agnostus pisiformis</i> v. <i>sociale</i> , Linrs. ...	Chilvers Coton, Oldbury, Stockingford Cutting ...	Olenus Beds, Sweden, Norway, etc.
<i>Agnostus</i> comp. <i>cyclopyge</i> , Tullb. ...	Stockingford Cutting, Griff	Olenus Beds, Scandinavia generally.
<i>Beyrichia angelini</i> , Barr. (M.)	Stockingford Cutting ...	Lower Olenus Beds, 2 <i>a</i> —2 <i>b</i> .
" comp. <i>nana</i> , Brög. (M.)	" " ...	Etage, 3 <i>a</i> , Norway.
<i>Leperditia</i> comp. <i>primordialis</i> , Linrs. ...	" " ...	Up. Paradoxides and Lower Olenus Beds, 1 <i>d</i> —2 <i>a</i> .
<i>Obolella salteri</i> , Holl. (M.) ...	Chapel End ...	—
" ...	Black Shales, Malvern... —	—
" ...	—	Comp. <i>C. exulans</i> , Linrs. of the Para-

<i>Lingula</i> sp.	"	"	Comp. <i>O. sabrina</i> , Shinetou	Comp. <i>A. sociale</i> , <i>P. forchammeri</i>
<i>Acrotreta</i> sp.	"	"	Shales...	Beds.
<i>Obolella sagittalis</i> (comp. Salter)	"	"	Black Malvern Shales	<i>P. forchammeri</i> Beds, Sweden.
<i>Hyalostelia</i> , sp.	—	—	—	—
<i>Protospongia fenestrata</i> , Salt. ...	—	—	—	—
Camp Hill or <i>Hyolithus</i> Beds.	—	—	—	—
<i>Orthotheca de geeri</i> , Holm. ..	Camp Hill Grange Quarry		—	"Green Shales," <i>Olenellus</i> Region, Bornholm.
" <i>johnstrupi</i> , Holm (M.) ...	"	"	—	"Green Shales," ditto.
" comp. <i>communis</i> , Billings...	"	"	—	(<i>Olenellus</i> Beds, Canada, New York.
" <i>corneolus</i> ? Holm. (M.)...	"	"	—	<i>Paradoxides ölandicus</i> Beds, Sweden.
" comp. <i>teretiusculus</i> Linns.	"	"	—	<i>Paradoxides ölandicus</i> Beds, Sweden.
<i>Hyolithus</i> comp. <i>princeps</i> , Billings	"	"	—	(<i>Olenellus</i> Beds, Canada, Nevada, etc.
" comp. <i>tenuistriata</i> , Lin (M.)	"	"	—	<i>Paradoxides forchammeri</i> zone, Sweden.
" comp. <i>lenticularis</i>	"	"	—	
Holm. (M.)	"	"	—	<i>Olenellus</i> Beds, Sweden.
" comp. <i>obscurus</i> Holm. (M.)	"	"	—	<i>Paradoxides forchammeri</i> zone, Sweden.
<i>Coleoloides typicalis</i> , Walcott ...	"	"	—	<i>Olenellus</i> Beds, Newfoundland.
<i>Stenotheca rugosa</i> , Walcott (M.)	"	"	St. David's	<i>Olenellus</i> zone, Troy, New York, Newfoundland.
" " var. <i>abrupta</i> (M.)	"	"	—	
Walcott	"	"	—	<i>Olenellus</i> Beds, Massachusetts.
<i>Scenella</i> sp. (M.)	"	"	—	Lower Cambrian, Newfoundland, etc.
<i>Autorginacinculata</i> , Billings ...	"	"	Mulverns, etc.	Cambrian generally, Georgia, Labrador, Sweden, etc.
" <i>labradorica</i> , Billings (M.)	"	"	—	<i>Olenellus</i> zone, Georgia formation, Vermont, Labrador, etc.
<i>Orthisina</i> comp. <i>transversa</i> , Wal.	"	"	—	
(M.)	"	"	—	<i>Olenellus</i> Beds, Georgia formation.

Wales, and their foreign equivalents. There is as yet no direct evidence forthcoming of the presence of the Lower Lingula Flags (Maentwrog and Festiniog beds) in the Nuneaton area ; but as the Nuneaton sequence appears to be continuous from base to summit it is just possible that they are represented by the upper bands of the Purley Shales and the lowest zones of the Oldbury series.

If the entire Cambrian sequence is here represented, it may not only be paralleled broadly with that of West Wales, Shropshire, and the Malvern Hills, but also with that of the N.W. Highlands of Scotland and that of Scandinavia.

The Hartshill Quartzite appears to be homotaxial with the Eriboll Quartzite of N.W. Scotland ; the *Hyolithus*-shales and limestone with the Fucoid shales and limestone containing *Olenellus* ; and the Camp Hill Quartzite with the overlying *Salterella*-Grit. In Scotland, however, in place of the argillaceous Stockingford Shales, we find the thick calcareous series of the Durness Limestone Group.

CAMBRIAN OF THE LOWER LICKEY HILLS.

The core of the long wedge-like range of the Lower Lickey Hills, extending from the neighbourhood of Barnt Green to the railway station of Rubery, about two miles to the north-eastward, is formed of a thick mass of quartzite, which rises in one locality (Coston Hill) to a height of more than 800 feet above the level of the sea.

This Quartzite, which is very similar in its general characters to the Hartshill Quartzite of Nuneaton, is laid bare in several natural and artificial sections. The best natural section is afforded by the transverse hollow at Rednal, where the Lower Lickey ridge is cut through by the little stream of the Arrow. The most conspicuous artificial section is seen at Rubery station, where the quartzite is at present being excavated for use at the Frankley reservoir, now in course of construction for the Birmingham Water Supply. This Lickey Quartzite has also long been utilised as road metal, and is cut into by many quarries often of great size, as at Bilberry Hill, Rubery village, and elsewhere.

Unlike the Hartshill Quartzite of Nuneaton, this Lickey Quartzite is much folded, jointed, and shattered. Neither the base nor the summit of the formation is exposed, and the disconnected sections do not afford a sufficiency of evidence to enable us to construct a complete ascending succession.

While the general course of the outcrop of the Quartzite ranges from S.E. to N.W., in consonance with the axis of the Lower Lickey Range itself, both the strike and the dip are very inconstant. Towards the southern extremity of the Range the beds are disposed, more or less, in a synclinal form, with

average N.W. strike. Towards the northern extremity of the Range they have an anticlinal disposition, and strike almost north and south.

What is probably the lowest division of the Lickey Quartzite is shown in the large quarry on the eastern flank of Bilberry Hill. Here the quartzite is more flaggy than elsewhere, and is made up of bands varying from 6 inches to about 2 feet in thickness, generally divided from each other by thin bands of sandy shale. The majority of the siliceous beds are distinctly quartzites; but some layers are soft in texture, and are in part composed of volcanic or tufaceous material—mainly felspathic; recalling, in this regard, some of the beds of the Barnt Green Rocks to the south. The shales are usually purple in colour, and somewhat micaceous.

The beds exposed in this Bilberry quarry strongly remind us, as a group, of those of the lower Hartshill Quartzite, not only in

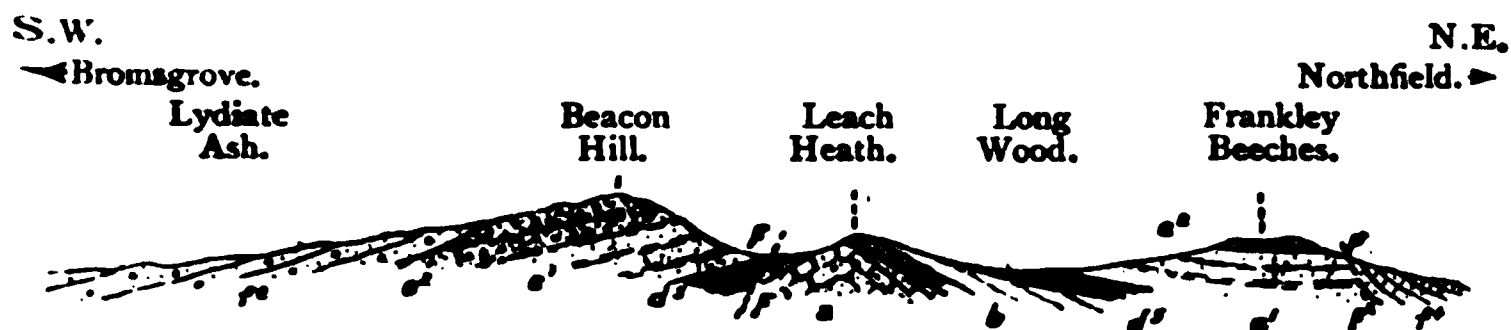


FIG. 8.—SECTION ACROSS THE NORTHERN PART OF THE LICKEY HILLS.—
C. Lapworth.

Trias	{ <i>f</i> ⁴ . Keuper Sandstone.	Silurian	<i>b</i> . Wenlock, Woolhope and Llandovery Rocks.
	{ <i>f</i> ³ . Bunter Pebble Beds.		
Permian	{ <i>e</i> ³ . Breccia.	Cambrian	<i>a</i> . Lickey Quartzite.
	{ <i>e</i> ¹ . Sandstones and Marls.		
Carboniferous	<i>d</i> ⁵ . Coal-measures.	<i>FF</i> .	Faults.

the thin-bedded character of the arenaceous zones and the abundance of purple shales, but also by the intercalated layers of what may be termed volcanic grits, which, indeed, sometimes take on the character of fine conglomerates.

The strata in this quarry are partly reversed by a remarkable overfold, and have been cut at the S.E. extremity of the exposure by a downthrow fault (Pl. XI, fig. 1).

In the Rednal Gorge the Quartzites are destitute of shaly bands, and are remarkably shattered. At Rubery Village the beds are more massive than elsewhere. They dip at a low angle to the eastward, and are overlain unconformably by the Llandovery Sandstone of the Silurian.

No fossils, except worm-burrows, have yet been detected in this Lickey Quartzite, but its lithological resemblance to the Hartshill Quartzite of Nuneaton, its unconformable infraposition to the Silurian of the district on the one hand, and its association with the pyroclastic (?=Caldecote) series of Barnt Green on

the other, render it practically certain that it is of Cambrian age and the local representative of the Quartzites of Hartshill and the Wrekin.

No traces of the Hollybush Sandstone, or of its equivalent, the Camp Hill Quartzite of the Nuneaton District, have yet been detected in the Lickey area.

Silurian System.

The strata belonging to the Silurian System appear to have extended originally in an unbroken mass over the whole of the Birmingham District, forming a thick sheet of fossiliferous deposits, which was not only in direct continuity with that of the typical Silurian of Shropshire, but was marked by the same lithological characteristics, and made up of the same natural divisions.

Like the Shropshire Silurian, the Midland series, regarded as a whole, is composed of a succession of blue and greyish green mudstones and shales, relieved upon certain definite horizons by bands of grey limestones, rich in fossils and of notable economic value. At its base this Silurian series rests unconformably upon an irregular surface, composed in part of Archæan and in part of Cambrian rocks. At its summit it apparently graduated upwards through the fish-bearing Passage Beds into the lowest strata of the Old Red Sandstone.

In the typical Silurian area of Shropshire the strata of the system crop out in a single broad and continuous band, which intervenes naturally between the outcrops of the pre-Silurian and post-Silurian systems of the country; the strata are very gently inclined, and the component formations are displayed in natural sequence from the base to the summit of the system.

The case, however, is very different with the corresponding strata of the Birmingham District. The Silurian rock sheet is here generally hidden from sight by the rocks of the overlying and newer systems, and its strata crop out only along the crests or flanks of a number of sharp anticlinal folds; while none of the Silurian exposures are more than a few square miles in horizontal extent. Where these Silurian strata are gently inclined only a mere fraction of the system is exposed; where, as in a few areas, the entire succession is displayed, the strata dip very steeply or are even inverted.

The Silurian exposures of the Birmingham District arrange themselves very naturally in two distinct groups, viz., those of the *Western, or Malvern-Abberley region*, and those of the *Central region* of the South Staffordshire Coalfield.

The longest and most continuous outcrop of Silurian strata in the district occurs along the course of the sharp anticlinal form of the Malvern-Abberley range—running almost directly N. and S.



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FIG. 1.—LICHELY QUARTZITE, BILBERRY HILL QUARRY, NEAR REDNAL.
The Quartzite is overfolded and cut by a fault.
(From a Photograph by Mr C. J. Watson.)



FIG. 2.—WENLOCK LIMESTONE, WREN'S NEST, DUDLEY.
(From a Photograph by Mr K. F. Bishop.)

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or a distance of at least twenty miles parallel with the Severn Valley, but not attaining a width of more than two miles.

In the central parts of the Birmingham District, in and around the South Staffordshire Coalfield, Silurian rocks are exposed in scattered patches, the majority less than a square mile in individual extent. These rise as isolated inliers through the unconformably overlying Carboniferous and Trias. None of these inliers show more than a fraction of the Silurian succession, but by piecing together the various sections met with in the several exposures it is demonstrable that all the typical Silurian formations, from the Llandovery to the Ludlow Limestone, are present in the same order and with the same lithological and palæontological characteristics, as in Central Shropshire and in the Malvern and Abberley Hills.

The Silurian formations occurring in the Midlands abound in organic remains, especially the strata of the inliers of the central parts of the district. They have long had a world-wide reputation for the number and excellent state of preservation of the fossils which have been collected from them. The well-known Silurian localities of the Dudley Hills have been famous in the geological world since the publication of Murchison's great work on *The Silurian System*. Bed for bed it is probable that these Midland Silurian rocks are no more prolific in fossils than their Shropshire representatives; but the Dudley limestones have been worked for centuries as a flux for the ironstones of the surrounding South Staffordshire Coalfield, and consequently abundant—and, indeed, unrivalled—opportunities have been afforded for the discovery and collection of the fossils of the limestones and those of the underlying and overlying shales. For many years—especially about the middle of the present century, when the limestone workings were open to the surface—these fossils were assiduously collected personally, or were purchased from the workmen, by local geologists and others. It may, perhaps, be safely asserted that the majority of the finest examples of British Silurian fossils now enriching the public and private geological collections, both in Britain and abroad, were originally obtained from the Silurian rocks of the Birmingham District.

The basal or *Llandovery* member of the Midland Silurian is a formation of coarse sandstone, usually of a red colour, occasionally conglomeratic in its lower zones, and containing, locally, pebbles and fragments derived from the degradation of the underlying Archæan and Cambrian rocks. In its higher zones the sandstone becomes of a finer grain, and occasionally grows markedly calcareous. The formation contains examples of *Pentamerus oblongus* and other characteristic fossils, which fix its age as that of the Upper Llandovery. No certain trace of the Lower Llandovery has yet been detected within the limits of the Birmingham District. The naturally succeeding formation—

the *Tarannon*, or *Purple Shale* of Siluria—is as yet unknown, at least in its typical lithological form, in the Midland areas; but certain bluish and pinkish shaly and flaggy strata with calcareous seams, which follow at once upon the Llandovery Sandstone group, may be looked upon as its probable equivalent.

The *Wenlock* formation is represented by its usual succession of nodular shales and mudstones, here from 1,000 to 2,000 ft. in thickness. The *Woolhope Limestone* (which is locally wanting in Shropshire) forms the base of the Wenlock series in the Midlands and attains a thickness of 150 ft. in the Malvern region. It thins gradually as it is followed through the district to the north and west, but it is found to be universally present where the lower Wenlock beds are laid bare in the Midland areas. In the South Staffordshire region it is generally known by the local name of the *Barr Limestone*, after the locality of Barr near Walsall, where it is richly fossiliferous but is reduced to only a few yards in vertical extent. The *Wenlock Shale* which succeeds, is of the same lithological character as the Wenlock Shale of Shropshire, but is much reduced in thickness. The *Wenlock Limestone*, which constitutes the final member of the series, is fully as conspicuous in the Midland region as in Shropshire; but, instead of forming a single bed as in the Wenlock Edge, it is made up of two distinct limestone zones, each from 20 to 30 ft. in thickness, which are divided from each other by a thick zone of nodular shales.

The *Ludlow* formation is complete in the Malvern and Abberley areas; showing the *Lower Ludlow* Shales at the base, a representative of the Ludlow or *Aymestry* Limestone in the middle, and the *Upper Ludlow* Shales at the summit. These last pass conformably upwards into the base of the Old Red Sandstone and afford fossils characteristic of the Passage Beds of Siluria. In the South Staffordshire areas the Lower Ludlow Shales and Aymestry Limestone are exposed only in a single inlier—namely, in that of the village of Sedgley between Dudley and Wolverhampton. This also is the only locality where the Upper Ludlow Beds are seen in the central areas, a few feet of calcareous shales intervening between the Sedgley Limestone and the unconformably overlying Carboniferous rocks. No higher Silurian strata are laid bare at the surface, but Silurian shales with characteristic Passage-Bed fossils were pierced in sinking for coal at the Manor Pits, near the town of Halesowen, in the South Staffordshire Coalfield.

SILURIAN OF THE MALVERN AND ABBERLEY AREA.

The southern half of this long and narrow anticlinal is flanked from Chase End to North Malvern by a strip of Silurian strata about a mile in width, which intervenes between the crystalline

of the hills and the wide-spreading sheet of the Old Red Sandstone to the west. On the eastern side the Triassic beds are faulted against the hills and the Silurian is unseen. In the northern half of the range (from North Hill to Abberley) the crystalline rocks disappear from sight, and both limbs of the shattered anticline, which is here nearly two miles in width, are constituted by Silurian strata. Along this Malvern-Abberley line the whole of the Silurian System is shown from base to summit,—its lowest strata resting unconformably upon the crystalline and Archæan rocks (except in the Eastnor district, at the south-west extremity of the range, where they transgress upon the various members of the Cambrian); and its highest beds everywhere passing up conformably into the basement layers of the Old Red Sandstone. In the extreme south of this long Silurian outcrop the strata dip at a gentle angle; in the central parts they are often very steeply inclined, especially where they are in contact with the Archæan rocks; while in the extreme north of the range,



FIG. 9.—SECTION ACROSS ABBERLEY HILL.—*W. Wickham King, after Phillips.*

- | | |
|--------------------------------|--|
| δ^s . Keuper Sandstone. | <i>c.</i> Old Red Sandstone. |
| <i>e.</i> Permian Breccia. | $\delta^{7''}$. Upper Ludlow Rocks and Downton Sandstone. |
| δ^b . Coal-measures. | $\delta^{7'}$. Aymestry Limestone. |
| | δ^7 . Lower Ludlow Shales. |

namely in the Abberley Hills themselves, they are excessively folded, often inverted, and in some cases completely overturned.

SILURIAN STRATA OF THE CENTRAL AREAS:—SOUTH STAFFORDSHIRE COALFIELD AND ITS NEIGHBOURHOOD.

The exposures of Silurian strata found in the central parts of the Birmingham District occur either within or upon the borders of the South Staffordshire Coalfield. They constitute nine distinct inliers:—namely those of (1) Walsall, (2) Sedgley, (3) The Wren's Nest, (4) Dudley Castle Hill, (5) Turner's Wood, (6) The Lye, (7) Rubery, (8) Rednal, (9) Kendal End.

Two of these inliers,—those of *Walsall* and *Turner's Wood*—lie upon the outer margins of the South Staffordshire Coalfield—the first upon its eastern, and the second upon its western edge. The inliers of *Sedgley*, *Wren's Nest*, and *Dudley Castle Hill*, lie upon the crest of the Dudley anticlinal, which traverses the Coalfield obliquely along a N.W. and S.E. line running from Wolverhampton through Rowley Regis; and the *Lye* exposure occurs at

the south-west end of the Netherton anticline, which crosses the S.W. division of the Coalfield about two miles east of Stourbridge. The Silurian exposures of *Rubery*, *Rednal*, and *Kendal End*, are met with a short distance outside the actual southern

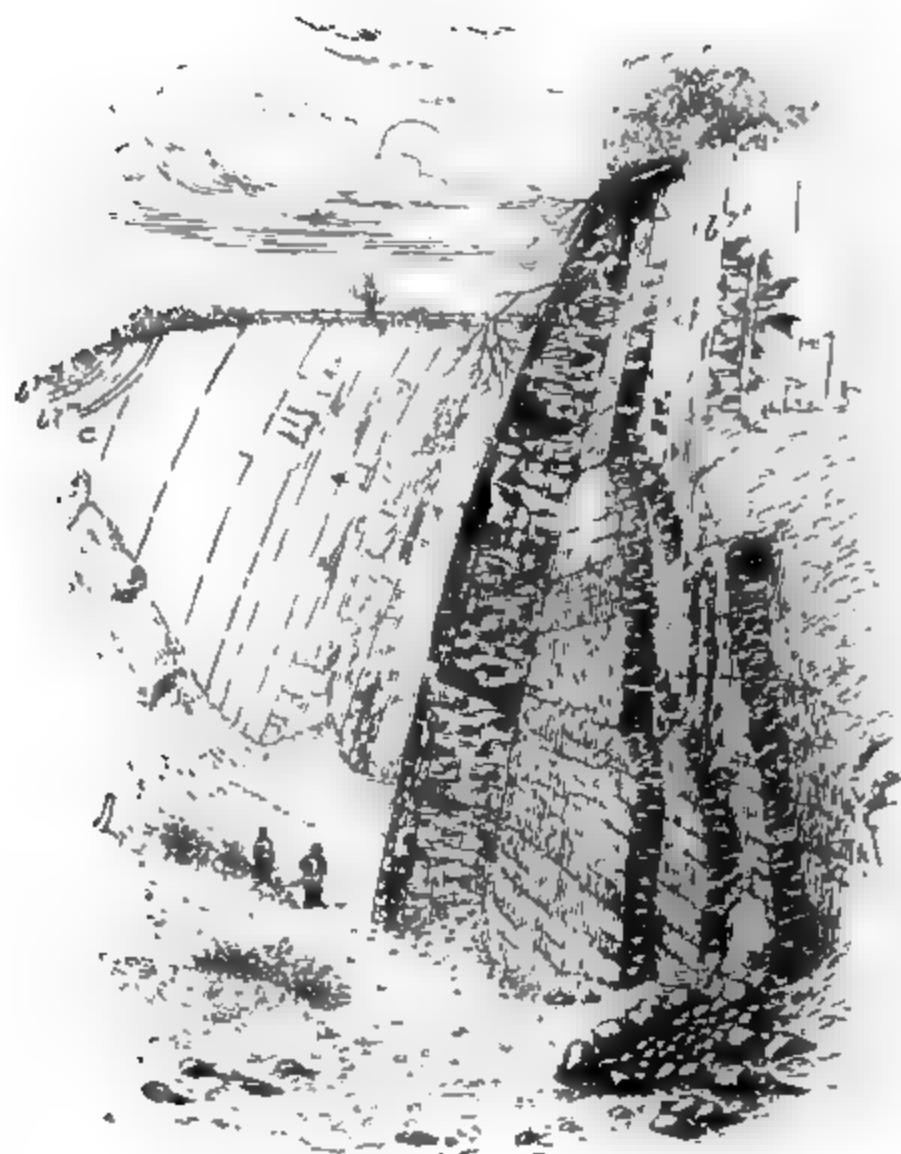


FIG. 10. —VIEW OF WALSGROVE QUARRY, ABBERLEY.

Showing inversion of Ludlow Rocks.

(*F. Raw, from a photograph by Mr. H. Evers-Swindell.*)

- c.* Old Red Sandstone.
- b7'* Downton Sandstone.
- b7''* Ludlow
- b7'* Aymestry Limestone.

boundaries of the Coalfield, and lie upon the crest and flanks — the anticlinal form of the Lower Lickey Hills.

Of these various inliers, that of Walsall (or Barr) is the most important from a geographical point of view, occupying an area of from five to six square miles. The inliers of the Dudley anticline are richest in fossils, and are those which are best known.

o geologists. The Silurian exposures of the Lickey Hills are small, but they are very noteworthy as presenting us with the basement beds of the system. The remaining inliers are of no great geological importance, and will not be noticed further in this place.

SILURIAN EXPOSURES OF THE LOWER LICKEY HILLS.

Llandovery Sandstone.—At the village of Rubery, near the northern extremity of the Lower Lickey Hills, there occurs an outcrop of coarse-grained sandstone a few square acres in extent. This sandstone, which is of no great thickness, is marked by the presence of abundant casts of fossils characteristic of the Upper Llandovery rocks. A good section of the sandstone is laid open on the southern side of the Birmingham and Bromsgrove Road, opposite the school-house of Rubery village. The lowest beds of the sandstone rest unconformably upon the beds of the local Cambrian or Lickey Quartzite. Irregular veins of the sandy material fill up hollows and fissures in the surface of the Quartzite itself, and angular chips and small pebbles of the Quartzite can be collected from the unaltered sandstone near its base. In mass, the Rubery Sandstone is of a dark red colour, its matrix is more or less calcareous, and its component grains are large, well rounded, and easily discernible with the naked eye; the sandstone is therefore readily distinguished lithologically, as a whole, from the pale, compact, and highly siliceous Cambrian Quartzite upon which it lies. Occasionally, however, it becomes pale in colour and the matrix more siliceous, and in these cases it is somewhat difficult to distinguish the sandstone from the quartzite in hand specimens; a circumstance which, in all probability, aided in strengthening the view of the earlier geologists that the quartzite and the sandstone formed one continuous deposit of Silurian age, and that the former graduated insensibly into the latter. No fossils are known to occur in the underlying Cambrian Quartzite, but they have been collected from the lowest layers of the sandstone which fills the superficial hollows of its upper surface. The actual line of unconformity is usually well marked lithologically, and hand specimens may occasionally be collected showing the actual plane of contact—the lower portion of the specimen showing the pale Cambrian rock with its siliceous matrix, and the upper portion the coarse-grained more or less calcareous Silurian sandstone.

The fossils found in the Llandovery Sandstone of Rubery village occur as casts, and are comparatively rare in the rock as seen *in situ* at this locality. The roadside wall at the spot, however, is built mainly of blocks of the sandstone and some of these are crowded with casts of Llandovery fossils.

The sheet of Llandovery Sandstone cut into in this exposure

extends continuously from this spot to Leach Heath, about a quarter of a mile to the S.E. It appears to fill a shallow hollow or bay in the Cambrian Quartzite, and crosses the Lower Lickey ridge from side to side. The area it occupies thus forms a part of the Lower Lickey range itself, but the portion of the ridge constituted by the Llandovery Sandstone is much lower than the sections formed of the Cambrian Quartzite.

Llandovery Sandstone almost certainly fringes the Cambrian Quartzite everywhere immediately to the eastward of the Lower Lickey ridge, ranging down the eastern flank of the ridge from Rubery to Barnt Green, hidden, however, for the greater part of its course by the unconformably overlying strata of the Carboniferous and Trias. Loose red sandstone blocks, rich in Llandovery fossils, have been met with in the Asylum grounds, and also in the stream course near the Lodge. A conspicuous inlier of the Rubery Sandstone with casts of fossils rises out from below the Trias of Rednal House, opposite the central part of the ridge; and fragments of the red sandstone have been met with at the Silurian locality of Kendal End near the southern extremity.

The fossils collected from the Rubery exposures and from loose blocks found in the Rubery stream or lying loose upon the fields, include examples of *Stricklandia lens*, *Pentamerus oblongus*, *Atrypa reticularis*, and other characteristic Llandovery forms.

Lower Wenlock Beds.—Following apparently in immediate succession to the Llandovery Sandstone of Rubery occurs a series of blue and grey shales and flags, including a well-marked band of limestone. These rocks are found in a few indifferent exposures in the stream which flows through the Asylum grounds immediately north of the Lodge, and are followed unconformably by the basement beds of the Carboniferous. The limestone is compact, flag-like, usually of a pale blue colour, and remarkably rich in fossils, which show that it is of Lower Wenlock age and is in all likelihood the local representative of the Woolhope Limestone of Malvern, and of the equivalent Barr Limestone of the Walsall inlier.

The following list of a few of the more characteristic fossil forms of this limestone is due to the researches of Mr. Wickham King: *Stricklandia lirata*, *S. lens*, *Pentamerus oblongus*, *P. undatus*, *Leptæna transversalis*, *Illænus barriensis*, *Encrinurus punctatus*, *Monograptus priodon*.

At the locality of Kendal End near the southern extremity of the Lower Lickey ridge, a patch of Silurian rocks was formerly worked for limestone, but the old quarries have become partly filled up, and no limestone is now visible. According to Murchison, the bed of Silurian limestone which occurred here rested in a highly inclined position upon the Lickey Quartzite. Although there are no visible exposures to be met with at the present time,

fragments of fossiliferous limestone, similar to that of the Asylum stream, are occasionally picked up, and support the view that a thin representative of the Woolhope Limestone once existed at this spot. As already mentioned, fragments of red sandstone similar to that of Rubery have also been met with. It is difficult to fix the actual limit of this Silurian patch, but the presence of the Woolhope Limestone at this spot affords a striking confirmation of the view that the Silurian beds overlie the Cambrian Quartzite along the whole of the eastern flank of the Lower Lickey range.

THE SILURIAN INLIER OF WALSALL.

This inlier of Silurian rocks is the largest in the central part of the Birmingham District. It is about two miles in width, and is limited to the eastward by the great Eastern Boundary Fault of the South Staffordshire Coalfield, and its strata are overlain unconformably in all other directions by the basement beds of the Coal Measures. The Silurian beds of the inlier include all the deposits between the Upper Llandovery and Wenlock limestone inclusive. The rocks lie at a gentle angle, and the maximum thickness exposed is probably not more than 1,000 feet.

The lowest rock in the inlier is the *Llandovery* or Mayhill *Sandstone*, which is here a thin band of sandstone, normally of pale yellow or brown colour, but occasionally white. Sometimes, as at Rubery, the matrix is calcareous, and the rock is locally rich in fossils. The usual Llandovery forms have been procured from this sandstone, among others, the characteristic species *Stricklandia lens*, *S. lirata*, *Encrinurus punctatus*, etc.

Barr Limestone.—A little higher up in the succession follows a well-marked band of fossiliferous limestone—the local Barr Limestone,—answering to the Woolhope Limestone of the Malverns. The limestone band has long since been worked out for economic purposes, and its place is now marked by a line of old quarries, most of them completely overgrown. This special locality (Hay Head) was once famous for the fine specimens it afforded of the characteristic Woolhope Trilobite—*Illænus barriensis*—which received its name from the parish of Barr, in which this quarry is situated. While the quarries were open this locality appears to have been a favourite hunting-ground for collectors.

Wenlock Shale.—The Barr Limestone is succeeded by a thick series of dark blue shales, locally rich in the ordinary Wenlock fossils. Exposures are rare, but fossils are obtained in abundance from the shales in the railway cuttings, at the locality of Five Lanes, and elsewhere.

Wenlock Limestone.—This occurs at the western extremity of the inlier. It is well seen in the railway cuttings within the limits of the town of Walsall, and is exposed in several neglected quarries in the neighbourhood. Here, as in the Dudley district, the pure and workable limestone is arranged in two distinct bands—divided from each other by a thick mass of nodular shales.

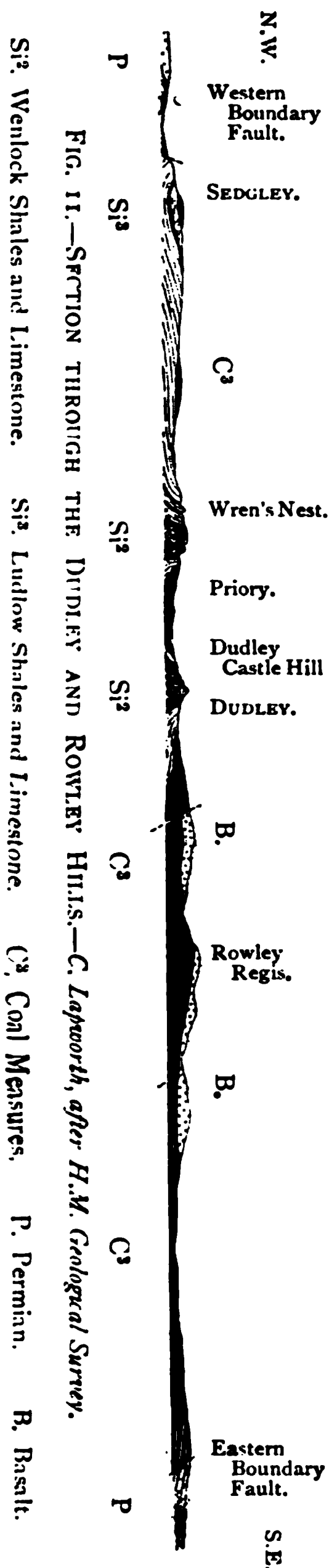
SILURIAN INLIERS OF THE DUDLEY HILLS.

Perhaps the most interesting and best known of the Silurian exposures of the Birmingham District are those of the Dudley Hills. These lie along the course of the Sedgley and Rowley anticline, which crosses the southern part of the South Staffordshire Coalfield from N.W. to S.E. The areas where the Silurian rocks are laid bare form three prominent hills, which are strikingly contrasted, not only as regard their elevation,—but also with respect to their scenery,—with the gloomy district of the surrounding Black Country.

Two of these hills—those of the Dudley Castle and the Wren's Nest—are steep, dome-like in form, and richly wooded from base to summit, rising like green islands out of the dark sea of Coal Measures which surrounds them. The third exposure—that of Sedgley Hill—which is the largest and highest of the three, is also bounded by Coal Measures on all sides except the west, where the ground drops down suddenly along the line of the great Western Boundary Fault into the rolling Permian and Triassic district of Baggeridge and Tettenhall. Like the two Silurian exposures last mentioned, the hill is well wooded, but it is traversed by roads and partly covered by houses.

In the hills of Dudley Castle and the Wren's Nest the Wenlock or Dudley Limestone forms the core of the elevation. In both it has been sharply bent up into an elongated dome-like form, the limestone crest of which has been partly denuded, so as to expose the underlying Wenlock shales in the heart of the hill. This Wenlock Limestone, as at Walsall, consists of two workable calcareous bands, separated by about 80 to 90 feet of valueless calcareous shales. The two limestones dip with great regularity from off the axis of each hill on the eastern and western sides of the dome at angles of from 25 to 30 degrees; but the dip rises to 50 or 60 degrees, and even higher, at the northern and southern extremities.

Both the hills have been mined for centuries, and the best limestone has been extracted to a great depth. The intervening and enveloping shales have been allowed to remain; so that the present structure of each of the hills is that of a central dome-like core of Wenlock shales surrounded by two enveloping shells of shale—the first formed of the calcareous shale—originally intervening between the two Wenlock Limestones, and the second of



the Lower Ludlow shale which follows. Between the three sets of shales occur the two more or less empty spaces marking the horizons from which the purer limestone has been extracted. Where the dip of the rocks is high these excavations form two deep and concentric moat-like hollows bounded by steep walls of shale. Where the dip is low the workmen were unable to extract the whole of the limestone and were compelled to leave occasional limestone pillars to support the superincumbent strata. Some of these pillared excavations are still open to the surface, as at the Wren's Nest, where they form magnificent caverns of peculiar weirdness and beauty. In the heart of the hills, at greater depths — as, for example, underneath Dudley Castle itself — the artificial excavations form subterranean caverns of remarkable extent, and when lit up by artificial light are very striking and picturesque.

The limestone beds of Dudley Castle Hill and the Wren's Nest have afforded some of the best known and the best preserved specimens of Silurian fossils. Many of the type specimens of Murchison's Silurian System came from this locality, but since the superficial limestones have been worked out, few good specimens have been obtained. An excellent collection of the fossils of Dudley and the Wren's Nest is laid out in the Dudley Museum, and another in the Geological Museum of the Mason College, while several good collections are in the possession of private individuals in Dudley and elsewhere. Perhaps the richest spots for fossils at present are the shaly slopes on the flanks of the Wren's Nest, where brachiopods and corals are locally abundant; but forms

belonging to other groups are rarely met with, and these generally in a very indifferent state of preservation.

While the inliers of Dudley and the Wren's Nest present us merely with the Wenlock Limestone, and a few feet of the underlying and overlying shales, the inlier of Sedgley shows a complete succession of the Silurian strata, ranging from the summit of the Wenlock Shale into the base of the Upper Ludlow Series.

The Upper Wenlock Shales and the overlying double Dudley Limestone are met with in the Sedgley area, forming a sharp anticline, at Hurst Hill, near the south-western extremity of the inlier. The limestone of this locality is followed to the west by the Lower Ludlow shales, which in their turn support a thick limestone band—the Sedgley (or Ludlow) Limestone. This limestone is arranged in a broad synclinal form, and its outcrop on the eastern side of the syncline forms the highest point of the Sedgley inlier—rising in Sedgley Beacon to a height of about 750 ft. above the sea level. Its outcrop on the western side forms a steep scarp, along the foot of which runs the line of the great Western Boundary Fault. The lowest Ludlow strata are also well developed, and have yielded the usual Brachiopods and Lamellibranchs.

The Sedgley Limestone is thicker, but is by no means as pure as the Dudley Limestone, and it has never been worked to any great extent for economic purposes. It is laid bare in some quarries near Sedgley Beacon, and has yielded, among other fossils the characteristic Aymestry Limestone form—*Pentamerus knightii*. There can be no doubt, as originally pointed out by the Rev. T. Lewis, that this limestone is the equivalent of the Aymestry Limestone of Siluria.

A few feet of the lower division of the Upper Ludlow rocks overlie the Aymestry Limestone, but exposures are not common; and no fossils have yet been published from these beds. In the centre of the synclinal at the village of Sedgley a cap of Carboniferous sandstone rests at once upon these Ludlow rocks, so that no evidences are at present obtainable of the original presence of the fish-bearing Passage Beds, or of the existence of overlying strata of Old Red Sandstone age in the Sedgley area.

Carboniferous System.

The Carboniferous strata of the Birmingham District, like those of the underlying Silurian, probably extended originally in a continuous and unbroken mass over a large proportion of the Midland region, with the doubtful exception of its S.E. division. In all cases, so far as known, the lowest beds of this system—as developed in the Midlands—repose unconformably upon the edges of the folded and eroded strata of the older systems below.—

In some local areas, as in Shropshire, Worcester, and Hereford, the basement beds of the system rest with a slight unconformity upon strata of Old Red Sandstone age, but gradually transgress upon the underlying Silurian; and in some areas, as near the Wrekin and elsewhere, even come to lie on the still older Cambrian and Archæan. In the S. Staffordshire district the Carboniferous deposits rest usually upon the Silurian rocks, the Old Red Sandstone being locally absent. In the East Warwickshire Coalfield they repose upon strata of Cambrian age; but the unconformability between the two systems remained undetected until quite recently (1886).

The actual form of the rocky floor upon which the Midland Carboniferous strata were laid down is only known in part, owing to the fact that, except along the line of the Severn between the Malverns and the Wrekin, that floor is buried up from sight by Carboniferous and post-Carboniferous deposits; but there are evidences that this pre-Carboniferous floor must have been of very irregular form. The ranges of Charnwood and the Malverns, of the Wrekin and the Longmynd, etc., were apparently already in existence, or had been blocked out in outline. Evidences have been gradually accumulating of late years which suggest that a set of connected ranges—or, at all events, a tract of elevated ground—must have extended across parts of the Midland region during the greater part of Carboniferous times; and that with this elevated region, the present core of the Malverns, the Lickey Hills, and the heights of Charnwood, appear to have been associated. But while our present evidences suggest that the most elevated parts of the rocky floor of the irregular basin in which the Carboniferous Strata of the Midlands were deposited lay along the south and south-eastern parts of the Midland District, it has long been known that the deeper parts of the basin and those to become first submerged lay to the north and north-west, along a line ranging from Coalbrookdale down the valley of the Trent, in the direction of the Humber. For while the Lower Carboniferous rocks are wholly wanting from the southern and central parts of the Birmingham District, representatives both of the Lower and the Upper Carboniferous rocks occur within its limits in that direction. Thus a thin representative of the Carboniferous Limestone occurs at the Clee Hills, at the Wrekin, at Lilleshall on the N.W. side of the district, and at the localities of Grace Dieu and Bredon Hill to the extreme N.E., near Charnwood Forest.

The Carboniferous Limestone is succeeded at all these localities by a representative of the Millstone Grit; this is, however, of no great thickness. In this northerly direction, the Coal Measures of the Midlands also attain their greatest development. In the North Staffordshire Coalfield three divisions are recognisable; (1) a Lower Coal Measure series, with occasional marine

fossils, 1,000 feet; (2) a Middle series with forty coal-seams, 4,000 feet; (3) an Upper series of undetermined thickness formed of brown sandstone, green conglomerates, and beds of red and purple mottled clays with bands of *Spirorbis*-Limestone.

As we pass to the S. and S.E. over the Midland areas the Carboniferous Limestone and the Millstone Grit eventually disappear, and the Coal Measures rest at once upon the pre-Carboniferous floor. At the same time the collective thickness of the Coal Measures themselves rapidly decreases, until in the latitude of Birmingham the total thickness is reduced to less than 2,000 ft., and the basement division has wholly disappeared.

At the first glance it would seem as if the floor of the great Midland Carboniferous basin must have sloped upwards somewhat rapidly from the N.N.W. to the S.S.E., and that the thinning away and eventual disappearance of the lower division of the system could be very easily accounted for upon the theory of the gradual submersion and filling up of the basin as a whole, and the consequent overlapping of the consecutive formations upon the inclined pre-Carboniferous floor as we pass over the Midland Carboniferous from N.W. to S.E. But while the theory of the slow submergence of the entire area may be regarded as satisfactory for the Midland Carboniferous when considered as a whole, there are many known phenomena among these deposits which make it clear that this general period of depression must have been interrupted by periods of local, if not of regional elevation and denudation. The rocky floor upon which Carboniferous rocks of the Midlands were deposited seems to have been greatly affected by the action of local crust-creep during Carboniferous time. Some areas were warped downwards, and received a more than ordinary thickness of Carboniferous deposits; others were warped upwards, and the older Carboniferous strata swept off them by the denuding agencies; while minor wrinklins and foldings of the pre-Carboniferous floor appear to have added greatly to the general complication.

In the western parts of the Birmingham District—from the Malvern Range through the Forest of Wyre to the neighbourhood of Newport in Northern Shropshire—the Carboniferous rocks form a more or less continuous band dividing the pre-Carboniferous from the post-Carboniferous rocks. Elsewhere they occur as inliers, surrounded by the great sheet of the Permian and Triassic rocks of the Midlands. The chief of these inliers is that of the South Staffordshire Coalfield, which occupies an area of about twenty-six miles in length by nine miles in breadth. The Warwickshire Coalfield is about fifteen miles in length; and the Leicestershire Coalfield has an area of about forty square miles.

Within the area of the South Staffordshire Coalfield the Coal

Measures, as already pointed out, rest upon the various members of the Silurian; but in the East Warwickshire Coalfield they lie upon those of the local Cambrian; in and around the Leicestershire Coalfield the three members of the Carboniferous System overlap each other when followed from N.W. to S.E., and some of the Coal Measures eventually rest upon the irregular floor formed of the Archæan rocks of Charnwood.

SOUTH STAFFORDSHIRE COALFIELD.

Both from its paramount economic importance and from the fact of its central position in the Birmingham District, the South Staffordshire Coalfield claims our first attention. Upon the whole this Coalfield may be defined as a broad anticlinal form of Carboniferous rocks, ranging N. and S., from which the originally overlying Permian and Triassic rocks have been denuded. This main anticlinal form, however, is broken up by three minor anticlines. The most important is that of the *Dudley Hills*, along which the Silurian rocks are laid bare; the second is the anticline of *Barr*, which exposes a broad area of the Silurian near Walsall, and is continued under the Coal Measures as a subterranean ridge—the so-called “Silurian bank”—which ranges southward through West Bromwich in the direction of Oldbury; the third is the anticline of *Netherton*, which warps up the Carboniferous in the S.W. part of the Coalfield, and exposes the underlying Silurian at the locality of the Lye.

Between these three subordinate ridges lie three shattered synclinal forms; the axis of the first and largest of the three ranges from Oldbury through Bilston towards Cannock, between the anticlines of Barr and Dudley; the second is that of Corngreaves and Halesowen, between the Netherton and Rowley anticlines; and the third that of Pensnett between the anticlines of Netherton and Dudley.

The Coalfield itself is limited to the eastward by the great “Eastern Boundary Fault,” which ranges from Rugeley through Oldbury to the neighbourhood of Northfield; and to the west by the great “Western Boundary Fault,” which ranges from the Clent Hills, through Stourbridge and Wolverhampton, to the district of Cannock Chase. Along these dislocations, strata of Permian and New Red age are faulted against the Carboniferous rocks. To the south of the Coalfield, however, the highest beds of the Carboniferous pass up with apparent conformity into the lowest beds of the “Permian” of the area of the Clent Hills; to the extreme north of the Coalfield the Carboniferous rocks are succeeded unconformably by the Triassic “Pebble Beds” of Cannock Chase.

The total thickness of the S. Staffordshire Coal Measures is

less than 2,000 ft., and the succession in the central and more typical part of the Coalfield is as follows :

(2) **Upper Coal Measures** 600-1,000 ft.

(c) *Spirorbis Limestone* group, a thin series of red, grey, and olive-coloured shales and sandstones with a band of *Spirorbis*-limestone and a few thin coaly beds.

(b) *Halesowen Sandstone* group, yellowish and reddish sandstones, with a few thin coals.

(a) Red and green *Coal Measure Clays* with beds of ashy sandstone and conglomerates.

(1) **Lower or True Coal Measures**, 500-1,050 ft. Grey and white sandstones with shales, clays, ironstones, and coal seams. Of these coal-seams the following are the most important :

(f) Brooch Coal, 4 ft.

(e) Thick Coal, 30 ft.

(d) Heathen Coal, 3 ft.

(c) New Mine Coal, 2 to 11 ft.

(b) Fire Clay Coal, 1 to 14 ft.

(a) Bottom Coal, 5 ft.

The most remarkable seam of the South Staffordshire Coalfield is that known as the Ten-yard or *Thick Coal*—a continuous bed of workable coal twenty-five to thirty feet in thickness. This underlies all the southern part of the Coalfield within the area enclosed by Smethwick, Oldbury, Dudley, Walsall, and Bilston. To the south, beyond Halesowen, it thins out and becomes mixed with shaly material. It is in reality composed of thirteen or fourteen superimposed coal seams, which form an apparently unbroken mass, but are easily distinguished individually by the practised Thick Coal miner. As we pass north from the typical Thick Coal area towards Walsall and Cannock Chase, the component seams become separated by intercalated sandstones and shales; so that, eventually, in the district of Essington and Pelsall, the Thick Coal is represented by fourteen distinct coals occurring at intervals in a mass of sandy and shaly strata, between 250 and 300 ft. in total thickness.

The Thick Coal is known to extend beyond the visible limits of the South Staffordshire Coalfield under the Red Rocks of the Birmingham District far to the eastward. The first attempt to reach it through the red ground was made under the guidance of the late Mr. Henry Johnson, of Dudley, at the locality of *Sandwell Park*, about one mile outside the limits of the Coalfield. The Coal was reached in 1873 at a depth of 1,250 feet, and was found to be of about the same thickness as in the Coalfield itself. The next successful attempt was made at *Hamstead*, about three miles outside the Coalfield proper, and was crowned with equal success, the Thick Coal being reached at a depth of 1,800 feet—

Large areas of Carboniferous ground have been opened up by these enterprises and the Thick Coal has been worked as far eastward as Handsworth and Perry Barr, immediately north of the city of Birmingham.

To the North of the Coalfield, where the Carboniferous rocks become covered up unconformably by the Triassic "Pebble Beds," the Coal seams of the northern parts of the Coalfield have been followed continuously beneath them into the district of Cannock Chase. Several pits have also been sunk through the Pebble beds into the Coal Measures below, and an entirely new coalfield may be said to have been developed of late years in this northerly direction.

The area immediately underlain by the outcropping Coal Measures, as already mentioned, constitutes the well-known district of the Black Country. In spite of its gloomy character it is one of the most populous districts in Britain, and includes within its limits the large towns of Dudley, Walsall, Wolverhampton, Bilston, West Bromwich, and others of scarcely less note. Indeed, it may be said that for its size the South Staffordshire Coalfield has proved itself perhaps the richest mineral area in Britain. Its thick coal-seams and its rich bands of ironstone occur within easy reach of the miner. Its central position has made it the great coal and iron mart of the Midlands, and the abundance and cheapness of the iron it affords have rendered Birmingham and the Black Country the best known hardware manufactory in the world.

The Carboniferous strata of the South Staffordshire Coalfield yield the usual Coal Measure fossils. Some of the shale beds locally furnish very well preserved Coal Measure plants, and the curious *Unio*-like shell *Anthracosia*; and the ironstone nodules afford fragmentary Crustacea and Insects. The marine fossils (which seem to be mainly confined to the beds below the Thick Coal) include such forms as *Discina nitida*, *Producta scabricula*, *Conularia quadrisulcata*, etc. Fish remains are also occasionally met with—*Megalichthys hibberti*, *Gyracanthus formosus*, etc.—as at Old Swinford, Brierley Hill, Dudley, etc.

The South Staffordshire Coal Measures are traversed by many dykes and sills of igneous rock. Of these the most important is the sheet known as the Rowley dolerite (*Rowley Rag*). This is about two and a-half miles long, and caps the long ridge of Rowley Regis, which rises to a height of 876 ft. above the sea-level. This sheet is pierced by several mining shafts, which pass through the dolerite sill into the workable Coals below. Many other masses of dolerite occur elsewhere in the South Staffordshire Coalfield, partly burning the coals and often rendering the mining locally difficult and costly. In the more central parts of the Coalfield several of these igneous masses (the "green rock" of the miners) are exposed at the surface, as at Barrow Hill.

S.W. of Dudley, and Pouk Hill, near Walsall. In the Rowley and Pouk districts the dolerite is occasionally columnar. Large subterranean masses of basalt occur also in the northern part of the Coalfield, but few traces of them appear at the surface. According to Prof. Jukes, these dolerite rocks appear to have been intruded previous to the final folding and faulting of the Coal Measures, as they take part in all the dislocations.

COAL MEASURES OF THE LOWER LICKEY HILLS.

Certain Coal Measure strata, which are probably the underground prolongation of the South Staffordshire Coalfield, occur on both sides of the anticline of the Lower Lickey Hills at the village of Rubery, and in its immediate neighbourhood. They consist of an insignificant thickness of yellowish sandstones, and green, grey, and white clays, with at least one coal seam about two feet in thickness, which was formerly worked at Rubery village, and was also met with in digging for the foundations of the Rubery Asylum. These coal-bearing strata repose immediately upon the Cambrian and Silurian rocks and subside below the "Permian" rocks of the district; and although no *Spirorbis*-Limestone has yet been recognised among them, they appear to belong to the highest, or *Spirorbis* group of the South Staffordshire Coal Measures.

EAST WARWICKSHIRE OR TAMWORTH COALFIELD.

The strata of this Coalfield floor a narrow strip about fifteen miles in length, ranging from Tamworth on the north to Bedworth to the south. They rest unconformably upon the Stockingford Shales of the Nuneaton Cambrian, and pass conformably upwards into the Red Sandstone or "Permian" rocks above. The successive divisions into which the Carboniferous strata may here be grouped, appear to be identical with those of the Coal Measures of South Staffordshire. The succession is as follows:

4. Grey and red sandstones and shales with a bed, or beds, of *Spirorbis*-Limestone.
3. White and yellow sandstones and shales.
2. Red and green brick-clays and marls.
1. Grey sandstones and dark shales, with five workable seams of Coal, *i.e.* the Four feet Coal, the Two yard and Rider Coal, Bare Coal, Slate Coal, and Seven feet Coal.

Not only is the sequence identical with that in South Staffordshire, but there is the same rapid decrease in collective thickness of the strata as they are followed from north to south.

In the northern part of the district the Slate Coal and Four feet Coal are separated from each other by more than 100 feet of sandstone; towards the south the sandstones gradually thin out—

and the coals come together, so that in Hawkesbury Colliery, to the south of Bedworth, all the coals practically combine into a single coal seam, like that of the Thick Coal of South Staffordshire, with a collective thickness of some 24 ft., but made up of the five distinct coals, which are here divided from each other merely by a few layers of shales and fire clays. It would appear, therefore, highly probable from these facts, that the South Staffordshire and East Warwickshire Coalfields were formed in the same general area of deposition and under the same sequence of physical conditions. In this case it becomes a matter of high probability that the Thick Coal of South Staffordshire extends more or less continuously under the Red rocks of North Warwickshire, possibly from Hawkesbury to Smethwick.

LEICESTERSHIRE COALFIELD.

The Coal Measures of this area, however, show little or no relationship to those of South Staffordshire and East Warwickshire. They consist of:—

3. An Upper series of coarse grits resting unconformably on the beds below.

2. A Middle series of sandstones, shales, and clays, with ten coal seams (1,500 ft.), one of which is from 10 ft. to 14 ft. in thickness.

1. The Lower Measures—sandstones, and shales, without coals.

THE SEVERN COALFIELDS.

We may group under this collective title those Coalfields which lie in part within the western limits of the Birmingham District, occurring along the valley of the Severn or upon the high grounds which drain into it. They include one main and continuous band of Coal Measures which ranges along the course of the Severn, from Newport on the north to the Abberley Hills on the south, constituting the Coalfields of Coalbrookdale and the Forest of Wyre; together with a few isolated areas of Carboniferous strata of minor extent which are found upon the summits of the Clee Hills. It is highly probable that all these Severn areas were once connected, the isolation of the outliers on the Clee Hills being due to circumdenudation. Assuming for the sake of description that such was originally the case, we find the whole of the Carboniferous sequence must have been represented. The Carboniferous Limestone occurs on the southern or Titterstone Clee; on the west margin of the Coalbrookdale Coalfield, in the neighbourhood of the Wrekin; and at the north extremity of that Coalfield near Newport. In these three

localities it is conformably succeeded by the Millstone Grit. Next follows the group of the Lower Coal Measures or Gannister Series—with marine fossils, sandstones and shales, and a few coals. This is met with only in Coalbrookdale. Above this come the typical or Middle Coal Measures; sandstones, shales, and clay, with ironstones and workable seams. These are well developed in Coalbrookdale, where they include several seams of coal varying from 1 to 6 ft. in thickness. Thirdly, follow the Upper Coal Measures, chiefly mottled shales, and greenish-grey sandstones, including a band of *Spirorbis*-Limestone. The coal-seams of this group are usually thin and insignificant.

In the *Coalbrookdale Coalfield* the group of the Upper Coal Measures, or *Spirorbis*-Limestone, group is locally unconformable to the strata below, and appears to lie in an old valley or estuary of the Middle Coal Measures—the irregular plane of contact being known as the great *Symon fault*. This inter-Carboniferous denudation and overlap at the base of the Upper Coal Measures or *Spirorbis* group appears to have extended over the whole of the Severn region to the S. of Coalbrookdale as far as the Abberley Hills.

The Coal Measures of the *Clee Hills* rest unconformably upon the Carboniferous Limestone and Millstone Grit, and those of the *Forest of Wyre* upon the Old Red Sandstone. The majority of the coal seams of the Forest of Wyre Coalfield are of a very indifferent quality, and the fact that beds of *Spirorbis*-Limestone are associated with the series shows that they belong mainly to the Upper Coal Measures. In some parts of the Coalfield, however (as near Kinlet to the west), coal seams apparently of Middle Coal Measure age are met with, in fair thickness and in workable condition (D. Jones).*

It is possible that the Halesowen Sandstone group, which intervenes between the true Coal Measures and the *Spirorbis*-Limestone group of South Staffordshire, was deposited in the interval marked in the Severn Valley Coalfields by the stratigraphical break between the Grey Coal Measures and the Upper Coal Measure group. Over most of the region of the Severn Coalfields these Halesowen sandstones appear to be unrepresented; but near Shatterford some barren Coal Measures several hundreds of feet in thickness were pierced, which may possibly represent this South Staffordshire formation.

* Daniel Jones. "The Forest of Wyre Coalfield." *Trans. Federated Institution of Mining Engineers*, vol. vii, 1894, p. 287.

Permian Rocks.

The strata which succeed the Coal Measures of the Birmingham district, and which are usually classed as of Permian age, are very distinct as a group from the typical Permian deposits of Nottingham, Yorkshire, and Durham. They belong to that special type of the British Permian which has been distinguished by Professor Hull as the *Salopian type*. No true limestones are present, and the group is composed of red sandstones, with occasional conglstones, marls, bands of calcareous conglomerate, and sheets of angular breccia.

As a general rule these red rocks follow conformably upon the Upper Coal Measures of the district. They succeed the highest acknowledged Carboniferous coals of the Severn Coalfields throughout the whole of the western area, along a line ranging from Newport to Arley; those of the South Staffordshire Coalfield in the slopes of the Clent Hills to the south of Halesowen; and those of the East Warwickshire Coalfield in the area extending from Baxterley to Bedworth. Along the east and west flanks of the South Staffordshire Coalfield these red rocks are faulted down against the typical Carboniferous strata, and their local conformity or unconformity with respect to the coal-bearing rocks is often a matter of uncertainty and dispute.

In the foregoing areas the Permian strata cover fairly large tracts of country, and vary locally in thickness from a few hundred to about two thousand feet. Elsewhere in the district, however, they occur in scattered and isolated patches, often of very insignificant extent, as along the eastern flanks of the Malvern and Abberley ranges, at Measham and Packington south of the Ashby Coalfield, in the neighbourhood of Polesworth near Tamworth, to the north of Sutton Coldfield, etc. In all these minor patches the so-called Permian rocks are of no great thickness, and are usually markedly unconformable to all the Pre-Permian rocks below.

These Midland Permians are everywhere eventually covered up unconformably, or irregularly overlapped by, the various members of the Midland Trias. They are succeeded by the Lower Bunter in the districts lying W. and N.W. of the South Staffordshire Coalfield, and by the Bunter Pebble Beds to the south and the east. They are surmounted by the Keuper sandstone throughout E. Warwickshire and Leicestershire, and also on the flanks of the Abberley Range.

In the Permian District of Enville and Arley, to the north-east of the Coalfield of the Forest of Wyre, three divisions are recognisable in these Permian Rocks, namely :

(3) *Upper red sandstones and marls.*

(2) *Middle group of sandstone and marls, with bands of conglstone and calcareous conglomerate, and a bed of "volcanic" or "trappoid" breccia.*

(1) *Lower red sandstone and marls.*

To the south of the Black Country the Permian gives origin to the bold range of the Clent and Romsley Hills. Here, however, only two divisions are recognisable, namely, the Lower red sandstones and marls, and the Middle division with cornstones, conglomerates and breccia. The Permian Breccia here attains its maximum thickness of about 450 ft. Followed northwards from these hills, along the east and west flanks of the S. Staffordshire Coalfield, the breccia soon dies out, and the Permian is represented mainly by thick masses of red sandstone and marls, with occasional cornstones. The Calcareous Conglomerates can, however, be followed northwards almost to Wolverhampton on the western side of the Coalfield, and on the eastern side to the neighbourhood of Barr.

Between Tamworth, Coventry, and Kenilworth, Permian strata cover a wide tract of country, and attain their greatest geographical extension within the limits of the Birmingham district. The red rock group is here made up of a thick series of red sandstones and marls with local conglomerates, and is practically identical in character and composition with the Permian rocks flanking the east side of the S. Staffordshire Coalfield.

In the Malvern-Abberley areas the local patches of Permian are almost wholly made up of the so-called Trappoid Breccia already mentioned.

In the Ashby areas the local patches of Permian strata, unconformably intercalated between the Coal Measures and Trias, rarely exceed 50 ft. in thickness. They consist of red and variegated marls, sandstones and bands of breccia, composed of fragments of the local Carboniferous and Charnwood rocks.*

By far the most striking member of the Permian succession in the Birmingham District is the "*volcanic*" or "*trappoid*" Breccia, which, in the Enville area, forms the most prominent member of the middle division of the collective series. The breccia is found in scattered patches over a superficial area of about 500 square miles, ranging from the southern end of the Malvern Hills to the neighbourhood of Enville, and from Church Hill in the Forest of Wyre Coalfield to the eastern flanks of the South Staffordshire Coalfield, west of Birmingham. In the Enville and Clent areas this breccia is conformably interbedded with the red sandstones and marls of the middle Permian; but in all the areas lying along the Malvern and Abberley Hills, it rests with a striking unconformity upon the rocks of the older formations—Carboniferous, Silurian, Cambrian and Archæan.

In all the localities where this remarkable formation is exposed its general lithological facies is practically the same. It is made up of angular fragments and masses (sometimes as much as 2 ft.

* Horace T. Brown, F.G.S., "The Permian Rocks of the Leicestershire Coalfield," *Quart. Journ. Geol. Soc.*, vol. xlv, 1889, p. 1.

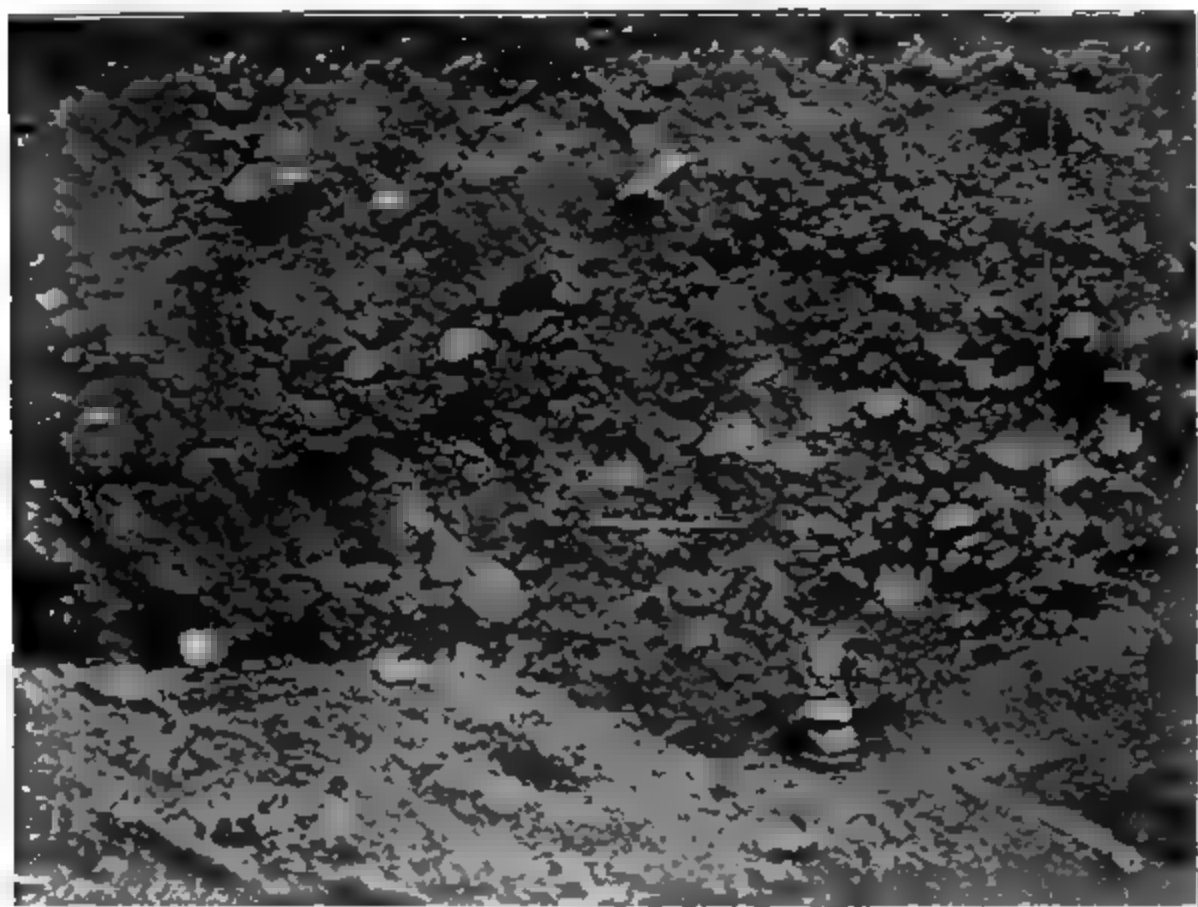


FIG. 1.—ABBERLEY (PERMIAN) BRECCIA.
Two-foot-rule ; the four stones marked X define the limits of an eight foot square on the face of the Quarry.
(From a Photograph taken in 1897 by Mr. H. Evers-Swindell, kindly lent by Mr. W. Wickham King.)



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FIG. 2.—RAILWAY CUTTING, NEAR MOSELEY STATION—GLACIAL SANDS AND GRAVELS.

(From a Photograph by Mr. W. Jerome Harrison.)

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in diameter) of volcanic rocks—lavas, tuffs, and volcanic grits, with occasional slabs or fragments of fossiliferous sandstones and limestones. These angular fragments are usually embedded in a matrix of sandy material or in a marly paste. Sometimes the stratification of the finer material is well marked, sometimes it appears to be wanting, and the formation becomes a pell mell of loose angular rock rubbish. The pyroclastic rock fragments are so abundant and characteristic in the breccia in all localities that the formation has long been distinguished by geologists as the *Trappoid* or *Volcanic* breccia.

As a group the prevalent volcanic rock fragments at once call to mind the dominant rocks of the Uriconian volcanic series of the Wrekin and Cardington Hills of Central Shropshire, and in a lesser degree, their Midland representatives of Caldecote, Barnt Green, and Herefordshire Beacon. A further resemblance is seen in the presence of abundant fragments of various volcanic conglomerates, compacted and banded rhyolites and porphyrites, and occasional vesicular rocks — principally andesites and melaphyres. Quartzites are not very common, nor are shaly fragments; but quartzites like those of the Lickey and Wrekin, and curious banded shales like those of the Stretton series of the eastern Longmynd are locally met with, while red grits like those of the western Longmynd (Bayston or Torridonian series), are by no means rare. Blocks and fragments of Upper Llandovery sandstones and flagstones, rich in characteristic fossils, are locally abundant, together with slabs of Wenlock Limestone; and in rarer cases, limestone fragments of Ludlow age. Few Carboniferous rocks occur, the chief being rolled fragments of coral bearing or encrinital Carboniferous Limestones.

Few British deposits have excited more interest or provoked keener controversy than the trappoid breccia. We will here confine ourselves to a few illustrative examples. Dr. Buckland originally described the breccia of the Clent region, noted its peculiar composition, and gave it as his opinion that like the other formations of the neighbourhood, it was a truly stratified deposit. Sir R. Murchison, on the other hand at a somewhat later date, was so impressed by the fact that the vast majority of these fragments were of volcanic origin, retaining their original angularity of form, and showing no evidence of transportation from a distance, that he felt assured that this outcrop of the Permian Breccia marked the position of underground masses of volcanic rock of Upper Carboniferous or Lower New Red Sandstone age which had become buried from sight under a cover of their own shivered fragments.

Professor Ramsay, however, during his subsequent survey of the district, soon placed it wholly beyond question that the formation was not the disintegrated surface of an igneous rock sheet, but, as Murchison had suggested, actually formed one of the

sedimentary members of the Midland Permian. He proved that not only was it locally stratified, but that, in the Enville district, it was both overlain and underlain by Permian sandstones and marls. He showed that the component fragments consist of rock types which, as a group, are distinct from those occurring at the surface in the areas occupied by the pre-Permian rocks in the Midlands, and could not, therefore, have been of local derivation. He identified the vast majority of the rock fragments, both volcanic and sedimentary, with the rocks which form the high grounds of the Wrekin, Caradoc, and Longmynd region of Central Shropshire, the lava and tuff fragments of the breccia being practically identical with the rocks seen *in situ* in the volcanic areas of the Wrekin and Cardington Hills (Uriconian), the slaty shales and volcanic gritstones being similar to those of the Longmynd, while the fossiliferous Llandovery sandstones and Silurian limestones were identical with those which unconformably lap round the Wrekin and Longmynd ranges themselves. He pointed out the striking similarity of this Midland breccia to an ordinary boulder clay, and stated that some of the included fragments were scratched in the manner of those of modern glacial deposits.

In his brilliant paper on the Permian Breccias' (*Quart. Journ. Geol. Soc.*, 1855, pp. 191, etc.), he boldly claimed that this remarkable formation must have been of glacial origin, and that it proved the existence of glacial conditions in middle Permian times. Its materials must have been brought down by floating ice or glaciers from the Wrekin-Longmynd area, the only region where all the formations represented in its fragments are found *in situ* in natural juxtaposition. In reply to the objection that the Longmynd-Caradoc region is at an average distance of from twenty to thirty miles from the localities where the breccia is now met with, and at a very little greater elevation, Ramsay pointed out that between the Longmynd Hills and the Midlands lies the long fracture-line of the Stretton fault, which has a calculated downthrow of some 2,000 ft., and that, if this fault did not exist the Longmynd region would tower some 2,000 ft. higher than the Permian districts of the Midlands, so that during the period of the Permian depression that region might have nourished glaciers or ice-sheets which descended into the surrounding sea and sent off ice-rafts laden with boulders and fragments over the more or less submerged Midland districts to the south.

Professor Jukes, who mapped the South Staffordshire Coal-field and its boundaries, on the other hand, while not controverting in general the views of his colleague, was inclined to the opinion that the angular fragments in the breccia might have been derived from rocks now concealed under the Permian and New Red Sandstone, and that, in some instances at least, as in the case of the exposures of the breccia near Northfield, the

included fragments of Silurian rocks had apparently "not travelled many yards from their original site, and that a peak, boss or ridge of Silurian sandstone lies concealed under the Permian rocks close by."

With the discovery of Cambrian fossils in the Nuneaton district in 1882, and the detection of the unconformity at the base of the Silurian in the Lickey Hills, the subject entered upon an entirely new phase. The Hartshill and Lickey Quartzites of the Midlands at once fell into line with the Quartzite of the Wrekin; the Midland Volcanic rocks beneath the quartzite became most naturally regarded as the actual underground continuation of those of the Volcanic Uriconian and other pre-Cambrian series of the Wrekin and Caradoc district, while the unconformable relation of the Midland Silurian to the Cambrian and pre-Cambrian rocks below became fixed beyond question. In other words, it became evident that in the very heart of the Midland area, even where these curious breccias are most fully developed, the geological succession among the pre-Cambrian rocks is absolutely identical with, or, at any rate, practically similar to that in the Wrekin-Caradoc country. Thus Ramsay's lithological arguments for the distant source of the special association of the rock-types represented in the fragments found in the Permian breccia lose their original force, and although there still remains the difficulty that the Midland pre-Permian rocks are largely buried up from sight by post-Permian deposits, Jukes' view of the local derivation of the materials of the breccia from Midland rocks, and not from the distant rocks of Central Shropshire, becomes not only possible, but exceedingly probable.

With the exception of those of the Malvern-Abberley district, and those of the Charnwood Forest area, no Midland pre-Permian rocks, from which these Permian breccias might have been derived, attain at present so great an elevation above the sea level as the Permian breccias themselves, and, upon the theory that these breccias are of local origin, it becomes necessary to postulate an upland area, ridge, or series of ridges of high ground crossing the Midlands in Permian times along a N.E. and S.W. line from Charnwood, through the southern end of the Lickey Hills towards the Abberley and Malvern ranges, from which their materials could have been derived. This difficulty, however, is not so great as appears at first sight. We have proof that this Midland tract of country was relatively higher than the districts both to the N.W. and S.E. of it on several occasions during the long period of geological time. Even in Ordovician time, as we have seen, while marine deposits were laid down over the Welsh region, they were not deposited over the Midland area, or were only deposited as thin, shallow-water, arenaceous beds.

Again, this range of country formed, later on, the dividing

line or ridge separating the lacustrine Old Red Sandstone from the marine Devonian. And, further, while the Carboniferous Limestone exists in great force both to the north-west and south-west, it is apparently absent from this tract of country. Indeed, as Jukes expresses it in his general survey of Midland geology, as given in his Memoir on the South Staffordshire Coalfield, "it is highly probable that all this tract of country between Leicester and Montgomery became land after the close of the Silurian period, rising perhaps very slowly, and undergoing a very gradual and long process of degradation as it passed through the destructive plane of the sea level, and it remained above the waters during the greater part of the period marked by the formation of the Old Red Sandstone and Carboniferous Limestone, and accordingly these rocks were never deposited upon it."

The main crest of these high grounds, the "Mercian Highlands," as we may call them—to adopt the title frequently employed by Mr. Wickham King—seems to have attained its maximum elevation in Permian times, when the breccias, sandstones, and marls of that age were accumulated in the hollows, the hill-sides were steep and the streams violent and intermittent.

In the succeeding Bunter times the Midland ridges were still further degraded, and the valleys more or less filled up by the coarse, sandy, and pebbly deposits derived from their ruins; finally, in Keuper times, the remaining irregularities were all brought to that general uniform level, or pene-plain, on which the succeeding Rhætic and Liassic strata seem to have been deposited.

The ridging up of the old pre-Triassic floor in the Midlands, as we have already mentioned, probably attained its maximum in the Permian period, when the denudation, which had already stripped off parts of the ridges their original covering of Silurian, progressed so far as to lay bare along their crests, first the underlying Cambrian deposits, and eventually the wide-spreading basement sheets of Uriconian volcanic rocks. Indeed, in those local areas where the Cambrian rocks were wanting, the pre-Cambrian volcanic rocks must have been laid bare immediately after the erosion of the Silurian. According to this hypothesis it was from these denuded areas of Midland Basement Rocks that the volcanic materials of the Permian Breccias, etc., were derived and not from the distant areas of Central Shropshire.

Of late years the study of the local composition, and of the place and mode of origin of the several areas and sheets of Permian breccia, has been taken up with great energy and success by Mr. W. Wickham King. He has discovered that the Permian breccias of these different areas, although possessing many common features, vary in the relative proportion and character of their volcanic, sedimentary, and fossiliferous constituents from area to area.

to area, and he has reached the conclusion that such variations are in harmony with the ascertainable facts of the local distribution of pre-Permian rocks in the Midland regions at the time in which the Permian breccias were laid down. The breccias of the Malvern-Abberley areas contain fragments of the peculiar rock-types of the Syenitic, Silurian, and Old Red Sandstone formations occurring *in situ* in these hills; the breccias of the Lickey region afford examples of the characteristic fossiliferous Silurian rocks of that area, and so on. The local derivation of the materials of the breccias, as a whole, seems to be confirmed by the rapid decrease in size of the fragments as the breccias are followed in a northerly and north-westerly direction, by the gradual rounding of the materials in this direction, and by the apparently total absence of fragments of Ordovician rocks.

As respects the *mode of origin* of these Midland breccias, Mr. King is of the opinion that they are local, sub-aerial torrential deposits, formed more or less of scree and talus, swept down in times of flood from steep hill slopes near at hand. By Mr. R. D. Oldham* they are regarded as a mixture of local moraine and scree-material, transported and deposited by streams.

The Triassic System.

The Triassic system, as already pointed out, is the Birmingham system *par excellence*. Not only is the city built upon strata of this age, but they overspread fully three-fourths of the area which we term the Birmingham District. Indeed, the surface of the Birmingham District, considered as a whole, may be broadly defined as that of a solidified sea of Triassic deposits, which fill up to one general level the hollows in a most irregular basin, or old land surface, carved out of Palæozoic rocks.

The main outcrop of the two divisions of the system, the Bunter and the Keuper, divide the Triassic district very fairly between them. All the Triassic country lying to the north-west of a line drawn from the Abberley Hills through Birmingham to Ashby (with the exception of the united synclinal areas of Brewood and Burton on Trent), is formed by the outcropping edges of the Bunter formations. All the Triassic area lying south and east of this line (with the exception of the narrow anticlinal area of the Lickey Hills) is floored by the component formations of the Keuper.

This special geographical distribution of the main outcrops of the two members of the Midland Trias is admittedly due in part to the general south-easterly dip of these rock formations, but only to a very minor degree. It is pre-eminently the natural consequence of the remarkable thinning out of the consecutive members of the Trias, as they are followed from the north-west

* R. D. Oldham, "A Comparison of the Permian Breccias of the Midlands, etc." *Quart. Journ. Geol. Soc.*, vol. 1, 1894, p. 463.

to the south-east, and to their successive overlaps upon the pre-Triassic floor of the district. In the north-western parts of the country, near Newport and Whitchurch, all the formations of the Trias are present from the Lower Variegated Sandstone at the base to the Keuper Marls and Rhætic at the summit, and the rocks of the system are fully a mile (5,200 ft.) in collective thickness.

But as we pass over the district from west to east, or from north to south (or, more generally speaking, from north-west to south-east), we find that not only do the component formations of the Trias decrease individually in thickness, but they die out one after the other in the order of their ascending succession ; so that when we reach the eastern and southern limits of the district the highest formation of the red rock series, namely, that of the Keuper Marls, is all that remains to represent the entire Triassic system.

In the areas lying west and north-west of the South Staffordshire Coalfield the Lower Variegated Sandstone forms the base of the system. Upon the flanks of the Coalfield itself the Lower Variegated Sandstone is absent, and the Pebble Bed reposes at once upon the pre-Triassic floor. A short distance farther to the eastwards, namely, the northern parts of the East Warwickshire and Ashby Coalfields, the highest Bunter formations also disappear ; and in Eastern Warwickshire the Keuper Sandstone rests unconformably upon the pre-Triassic rocks. Finally, in the southern part of the Charnwood Forest region, even this has vanished, and the Keuper Marl runs up in long fiord-like arm between the more or less buried Archæan heights, and the horizontal layers of the marl end off suddenly against the steep sides of the ancient hills and glens of the pre-Triassic landscape.

The following table gives a rough index of the decrease in individual thickness, and of the overlap of the successive formations upon the floor of the pre-Triassic basin as they are followed across the district from west to east :

	Central Cheshire.	West and South Sides S. Stafford Coalfield.	East Side of S. Stafford Coalfield.	East Warwick.	Char- woo- d Fore- est. etc.
Keuper Marls .	3,000 ft.	1,000	700	600	600-0
Keuper Sandstone (or Waterstones) .	450 "	400-300	200	150	Ab=ent
Upper Variegated Sandstone .	500 "	300	} 300-250	Absent	Ab=ent
Pebble Beds .	750-500 "	300		Absent	Ab=ent
Lower Variegated Sandstone .	500-200 "	300-0	Absent	Absent	Ab=ent

As a general rule the Triassic strata are very gently inclined, the dip rarely exceeding 10 degrees, and in the majority of cases ranging from about 2 to 5 degrees. Two of the formations, namely, the Pebble Beds and the Lower Keuper Sandstone or Waterstones, are relatively harder than the rest, and their outcrop is frequently marked by low hill ranges, or in many instances by conspicuous lines of elevation, often limited by a steep scarp, usually facing to the north-west. In the areas occupied by the Bunter formations the soft Variegated Sandstones are eroded into long and broad valleys, divided from each other by ridges formed of the hard Pebble Beds. Where, as in the districts north and north-east of the South Staffordshire Coalfield, the Pebble Beds spread out over a large area, they give origin to wide undulating uplands often marked by broad stretches of open heath. The outcrop of the Keuper Sandstone usually forms a tract of comparatively high ground, well watered and richly wooded. The Keuper Marls nowhere rise to any great elevation. They spread out over broad areas traversed by the larger rivers and watered by countless minor streams, and form the floor of some of the finest stretches of agricultural land within the limits of the district.

BUNTER FORMATIONS.

Lower Bunter or Lower Variegated Sandstone.—The Lower Variegated (or Mottled) Sandstones fringe the great broken syncline of Trias, which lies between the Severn Valley and the Black Country, and ranges south from Brewood to Kidderminster. On the western side of this syncline they rest unconformably upon the Permian and Carboniferous rocks; and upon the eastern side they are either faulted against the Permian and Carboniferous rocks, or they are locally wanting. The formation attains a thickness of about 650 ft. at Bridgnorth, but is reduced to about a third of that amount at Stourbridge, and disappears altogether a few miles to the north and south of that town.

The strata of the formation are invariably sandstones, usually reddish brown in colour, but they range from yellow through brown to vermilion. As a group they are remarkably false-bedded, and are easily distinguished from the succeeding formation by the total absence of pebbles.

Good sections are met with at Bridgnorth and Bewdley, but perhaps the most interesting is that afforded by the escarpment of Kinver Edge, where the top beds of the group are hardened by a calcareous cement, and look out to the west over a deep and irregular valley worn out of the softer members of the formation. In and near a detached mass of sandstone in the immediate neighbourhood, called the Holy Austin Rock, some artificial caves or rock houses have been excavated. Certain yellow sandstones

near Barr Beacon, which apparently underlie the Pebble Beds of that locality, have been identified as belonging to this Lower Mottled Sandstone*, but if so this is the only known locality where the rocks of this basement division occur to the east of the South Staffordshire Coalfield.

The Middle Bunter, or Bunter Pebble Beds.—This remarkable division of the Bunter is well developed within the limits of the north-western half of the district, but is unknown to the south-east.

Wherever the formation presents itself under its more typical aspect it is seen to be made up of a mass of well-rounded pebbles, usually more or less elongated, and varying in size from a pigeon's egg to that of a man's head. The majority are yellow, brown, and occasionally chocolate, or even dark liver-coloured, quartzites. Pebbles of hard, grey sandstone and volcanic grit, are occasionally met with, and in some localities, especially to the south-west, in the Clent and Lickey range, abundant pebbles of silicified limestone. Pebbles of more or less rotted limestone with Encrinites are not uncommon in the Sutton and Lichfield areas, and rounded pieces of volcanic rock, granite, and hardened slates occur locally. Many of the pebbles, especially in the Sutton District, are deeply indented, and are frequently found to have been cracked *in situ*, falling to pieces when removed from the parent rock. In some localities the formation is a loose aggregate of pebbles set in an open sandy matrix; where, however, the rock has been cut through at great depths underground, as in wells and borings for water, the matrix seems to be highly calcareous and is often intensely hard, any fracture passing through pebbles and matrix alike. Sometimes the pebbles are less conspicuous, and the group is made up of alternations of pebbly and sandy zones. Sometimes the larger pebbles are wanting altogether, and the formation is represented by coarse, false-bedded sandstones, with occasional small pebbles scattered here and there in the body of the rock.

In the great Triassic syncline to the west of the South Staffordshire Coalfield, this Pebble Bed formation is the middle member of the local Bunter division, lying, with apparent conformity, between the Lower and Upper Variegated Sandstones, the outcrops of the three forming parallel bands. It here attains a thickness which has been estimated at from 300 to 650 feet. Its basement-bed in the Bridgnorth district is a hard breccia formed of angular fragments, which passes gradually upwards into the hard conglomerates of the group, but rests below in the hollows of an eroded surface of the Lower Variegated Sandstone. Although the stratigraphical relations at this locality are suggestive of unconformity, this does not seem to be the case elsewhere in the western area.

The outcrop of the Pebble Beds in this western area averages about a mile in width, and ranges continuously north and south

* Landon *Proc. Birm. Phil. Soc.*, vol. vii, 1889-91, p. 113.

from Newport to a point near Bridgnorth (16 miles). From this locality it is thrown, by a transverse dislocation, some three miles to the north-east, to the neighbourhood of Claverley; thence it sweeps in a long and gentle curve, convex to the east, through Abbot's Castle Hill, Kinver Edge, and Kidderminster to the banks of the Severn, where it disappears as it is faulted against the Coal Measures of the Forest of Wyre. Throughout most of its course from Newport to Bewdley, this outcrop of the Pebble Bed formation is marked by a ridge of high ground, with a steep scarp to the west, and a gentle slope to the east in the direction of the dip of the beds. Some of the ridges, formed by the Pebble Bed group along this course, are conspicuous features in the landscape, as Pendlestone Hill near Bridgnorth, Abbot's Castle Hill near Trysull, and the fine escarpment of Kinver Edge, between Enville and Kidderminster.

The size of the pebbles along this line is very variable, and the rock sometimes becomes a sandstone, containing only a few scattered pebbles of comparatively small size. While the pebbles are dominantly formed of quartzite, there are abundant examples of other rocks, such as vein quartz, blue and grey limestones with Carboniferous and Silurian fossils, grits, and sandstones of various colours and ages, with occasional volcanic rocks, slates, and lydian stones. Sometimes the matrix is calcareous and intensely hard, at other times the rock often degenerates into a loose gravel.

Along the eastern side of this syncline there occur strips of the Pebble Beds, ranging south from Church-hill through Kingswinford, Himley, and Bushbury, to the town of Cannock where they merge into the broad expanse of Pebble Beds of Cannock Chase. They are much cut up by faults, and in the southern half of the area, where they are apparently faulted repetitions of the western outcrops, they rest conformably upon the Lower Variegated Sandstone, and in the northern half, where they dip west from off the flanks of the South Staffordshire Coalfield, they lie unconformably on the Permian. Some good sections are seen along the southern part of their course where they form the conspicuous fir-covered scarp of Wollaston Ridge, west of Stourbridge.

Broadly speaking it may be said that the Pebble Beds attain their widest geographical extension along the outer margins of the anticlinal form of the South Staffordshire Coalfield and its flanking Permian areas. The Pebble Beds dip off this anticlinal axis all round the Coalfield, but their outcrop is by no means continuous. Wherever the base of the formation is seen the Pebble Beds rest at once upon the eroded edges of the Permian or Carboniferous rocks, occasionally a few feet of loose sandstone intervene, which are doubtfully representative of the Lower Variegated Sandstone. Often, however, the Pebble Beds are faulted against the older deposits.

The narrow complicated strip of Pebble Beds running up the western edge of the Coalfield from Stourbridge to Cannock has already been mentioned. North of the Coalfield the outcrop of the Pebble Beds forms the district of Cannock Chase, a wide, undulating heathy moorland, some six miles in breadth, ranging northward to the valley of the Trent. Here the Pebble Beds, which rest at once upon Coal Measures, are exposed in many artificial excavations, and contain, in addition to the rock varieties already mentioned, a notable proportion of Carboniferous Limestone pebbles, Carboniferous grits, with flagstone and purple grits containing much volcanic material.

To the south of the Coalfield the Pebble Beds occupy an undulating area about $9\frac{1}{2}$ miles in length, extending from Blackwell to Stourbridge, and ranging along the southern slopes of the Lickey and Clent ranges. To the east the outcrop of the formation is broad and fairly continuous; it is 18 miles in length, and extends from the neighbourhood of Harborne, through Handsworth and Western Birmingham, Perry, and Sutton Park (where its outcrop is $3\frac{1}{2}$ miles wide), practically to the City of Lichfield.

Good sections of the Pebble Beds are met with in Sutton Park and the surrounding district—one near Blackroot Pool giving a vertical section of about 30 feet. There are few good sections in the Lickey area or to the west of Birmingham; one at Snails Green, near Barr, and one in the neighbourhood of Lichfield are, however, perhaps worthy of mention.

The Pebble Beds are met with again in a small area to the north-east of the Warwickshire Coalfield. They occupy several long and narrow strips on the flanks of the Ashby Coalfield, where, however, they are of no great vertical thickness.

Palæozoic Fossils of the Pebbles of the Middle Bunter.—The unaltered Carboniferous Limestone pebbles afford the usual fossils of that formation, and are fairly abundant in the more northerly exposures of the Pebble Beds; in the south the limestone pebbles are usually more or less silicified, and fossils are rare. Quartzites and grits with Devonian fossils—such as *Spirifer venustus*, *Homalonotus*, etc., are only occasionally met with. Silurian sandstones and grits, both calcareous and silicified, are by no means uncommon, and are often rich in characteristic fossils—especially in Llandovery forms. Perhaps the most interesting fossils, however, are those afforded by certain grey, purple, and brown quartzites which are of Ordovician age. These fossils include the well-known *Lingula lesueurii* of the *Grès Armoricaïn* of the west of France and many Lamellibranchiata. There are also Ordovician forms of somewhat later date—*Orthis huddleighensis*, *Glyptocrinus basalis*, etc., like those of the *Grès de May* and the Welsh Bala formations. Some good collections of these fossils from the Bunter Pebbles have been made by the late Mr. Molyneux, and by Mr. Harrison and Mr. T. Evans, of Birmingham.

Mode and Place of Origin of the Bunter Pebbles.—The two closely related problems of the original source or sources of the fossiliferous and non-fossiliferous Bunter pebbles, and the cause or causes of their present association and distribution have long fascinated the working geologist, and

many and diverse are the opinions which have been advanced. As regards the *agency* to which they owe their rounded form and present associations, they are regarded by some as being wholly of marine origin—the products of strong wave action, current action, or tidal action—like the pebbly accumulation of the recent Chesil Beach. By others they are looked upon as being wholly of fluvial origin, having been rounded by the action of flooded rivers and torrents, and deposited as deltas in freshwater lakes, or spread out in the lowlands at the foot of steep hill ranges as sub-aerial fans or alluvial deltas, in the manner of the Nagelfluh of Switzerland, or the Sivalik of Northern India.

As regards the rock formations from which they were derived, it has been urged by some that they originated in the breaking up and disintegration of earlier British *conglomerate formations*, like those of the Old Red Sandstone of Scotland and the like; by others, that they have all originated from the natural erosion and weathering of ancient *solid rock formations*, which were bared to the atmosphere, broken up into fragments by ordinary meteoric action, and rounded into pebbles during Bunter times.

As regards their geographical source, or sources, of derivation, it has been contended by some that they are more or less of *distant* origin. According to one view, they came from the *north*, having been brought from Scotland and the north of England; according to another, they were derived from the *south*—from barriers or high grounds lying towards southern England, or even as far distant as the English Channel and the west of France. By others it is believed that they are all probably of more or less *local* origin, having been derived from those ancient ridges of rock that diversified or bounded the Triassic basin, of which the Wrekin, Caradoc, the Longmynd, the Malverns, the Lickey, and Charnwood are at present almost the only unburied remains, and that they were spread out in the intervening Triassic valleys and plains at no great distance from their parent rocks.

Upper Bunter or Upper Variegated Sandstone.—The outcrop of the Upper Variegated Sandstone follows the course of that of the Pebble Beds along the valley of the Severn from Newport to Bewdley, where the rock attains a thickness of from 500 to 600 ft., and also around all sides of the anticline of the South Staffordshire Coalfield, where, however, its thickness is very much reduced.

Its strata are very similar in composition to those of the Lower Variegated Series, consisting of fine-grained sandstones, usually of a bright red or vermilion tint, and locally variegated or mottled with bands and blotches of white or pale yellow.

The formation is everywhere more deeply eroded than the flanking Pebble Beds and Keuper sandstone, and it usually floors a narrow tract of low ground bounded by conspicuous heights. The best sections occur in the Severn area, near Stourport (*the Redstone Rock*), where the strata of the formation are laid bare to a depth of 300 ft. They here contain intercalated bands of angular fragments and pebbles, a phenomenon not uncommon in this neighbourhood in both the underlying and overlying formations.

In all the regions lying west of the South Staffordshire Coalfield the Upper Variegated Sandstone covers large tracts of country, and the important towns of Stourport and Stourbridge are built upon it. A strip of the Sandstone overlies the Pebble

Beds to the south of the Coalfield, on the flanks of the Clent and Lickey range, and a good section is shown at Blackwell Station.

East of the South Staffordshire Coalfield the Upper Variegated Sandstone sweeps north from the Lower Lickey Hills, through Birmingham (where its outcrop is about one mile in width), to Lichfield and Rugeley. One of the finest sections of these beds occurs within the limits of Birmingham city itself, namely, in the cemetery near the G. W. Railway station at Hockley, where the sand has long been worked for moulding and foundry purposes. The exposures in the Sutton and Lichfield areas are few and fragmentary. East of a line drawn north and south through the centre of the Birmingham District the beds of this division appear to be wholly wanting.

KEUPER FORMATIONS.

The Keuper of the Birmingham District is made up of the so-called Lower Keuper Sandstone and the Keuper Marls. The former is one of the most consolidated members of the Midland Trias, and usually gives origin to ridges of high ground, whose steeper scarps look out over the lower grounds or open vales marking the outcrop of the underlying Upper Variegated Sandstone, whilst their gentler slopes die down in the opposite direction, towards the broad rolling lands floored by the denuded Keuper Marls.

Everywhere to the west and north-west of the Black Country the stratigraphical relationship between the Keuper and the Bunter appears to be that of a general conformity, but the base is usually marked by the presence of a breccia or conglomerate, often resting in hollows on the surface of the underlying strata. On the southern and eastern sides of the Black Country the basement conglomerate and breccia are often wanting, and the relations are sometimes those of apparent conformity, sometimes of absolute unconformity. In the areas of the East Warwickshire and Ashby Coalfields the Keuper Sandstone rests at once unconformably upon the Palæozoic rocks, and the entire formation is reduced to a homogeneous group of pale red sandstones and marls with few or no breccias or conglomerates.

Lower Keuper Sandstone.—As a general rule three divisions are recognisable in the Keuper Sandstone. The lowest, or *basement* group is formed of coarse sandstones, with calcareous breccias and cornstones and occasional beds of marl. The middle division consists of fine-grained sandstones, often forming excellent building stone (Bromsgrove, Hill Top, etc.). The upper division is made up of brownish red laminated sandstones and flags with sandy marls, and is locally known by the name of the *Water-stones*—a title which is very frequently applied to the whole of the Lower Keuper formation in general.

The Basement series is well shown in the neighbourhood of Stourport and Witley, where it often contains local beds of breccia, and rests unconformably upon the underlying Bunter and Palæozoic rocks. The hard calcareous beds give origin to prominent scarped hills in the Brewood and Albrighton area. The widest spread of the Lower Keuper Sandstone ranges north-west across the country from the Abberley Hills to the Clents near Hagley and Stourbridge, where a good section is seen in the railway cutting. South-west of the Lickey Range it occupies a broad triangular area, having the town of Bromsgrove for its centre; the hard calcareous division at the base is here very conspicuous, as is also the pale-coloured building-stone group near the summit. East of the Lickey range the formation sweeps through faulted ground from Barnt Green to Selly Oak, several good sections being afforded by the railway cuttings, and in the quarries at Weoley Castle and elsewhere. At Edgbaston its outcrop expands to about half a mile in width, and, limited by the great Birmingham fault to the east, it sweeps through the centre of the city in a continuous band, forming the higher ground occupied by the more important streets and the chief public buildings—the Town Hall, St. Philip's Church, the Mason College, the Council House, etc. It is continued under the suburbs of Aston, Erdington, and Wylde Green to Sutton Coldfield, beyond which it passes through a much faulted area to the city of Lichfield and the town of Rugeley, and is prolonged far into the valley of the Trent.

In the East Warwickshire areas the Waterstones or Lower Keuper sandstones are not of any great thickness. They rest unconformably upon the Palæozoic rocks, and consist, for the most part, of pale pink and yellow or white sandstones, with local seams of sandy marl. The outcrop of the formation fringes the Palæozoic district from Nuneaton, southward to Leamington, and from Warwick northward to Berkswell and Maxtoke. Some inliers also occur, like that upon which part of the city of Coventry is built (Andrews).

Fossils are occasionally met with in these Lower Keuper Sandstones. The Triassic fish *Dipteronotus cyphus* was obtained from a cutting in these beds near Bromsgrove Station. Bones and teeth of several species of *Labyrinthodon* (*Labyrinthodon jägeri*), *Cladyodon*, *Hyperodapedon*, have been procured at various times from quarries near Warwick, and several of these are now in the Warwick Museum. Footprints of animals and fragments of plants are occasionally met with in the Building-Stone group.

Economics and Scenery of the Waterstone Areas.—The narrow bands of Midland country floored by the outcrop of these Waterstones or Lower Keuper Sandstones—rich in springs of good water, relieved by swelling hills or picturesque scarps, and adorned with a luxuriant growth of trees—were those which

were naturally selected by the ancient inhabitants of the district as the sites of their earliest permanent settlements. Since the dawn of history they have always remained the favourite dwelling grounds for the inhabitants of the Midlands. All the older towns of the district—Warwick, Coventry, Nuneaton, Tamworth, Bromsgrove, Birmingham, Sutton Coldfield, Lichfield, Penkridge, etc.—are built upon the outcrops of the Waterstone formation; and the favourite suburbs of these towns lie along its outcrop—Edgbaston, Erdington, Tettenhall, Stourbridge, Leamington. Not only do we find upon it most of the mansions of the older nobility, such as Witley, Himley, Hagley, Hewell, Warwick, Edgbaston, etc., but its course round the South Staffordshire Coalfield is marked by the sites of the country or suburban villas and grounds belonging to those whose wealth enables them to satisfy their natural craving for a home for themselves and their families in the healthiest and most picturesque parts of the District.

Keuper Marls.—The outcrops of the Keuper Marls occupy a collective area almost as large as those of all the other Triassic formations combined. This area, however, although actually continuous, is of a most irregular form, spreading out in wide expanses in the broader synclinal forms and narrowed almost to straits between the grander anticlines. To the north the Keuper Marls floor the main valley of the Trent from Cannock Chase to the Ashby Coalfield. To the north-west they form a long strip, some eight or nine miles in width, ranging down the Brewood syncline from Stafford to Wombourn. But the three largest expanses are those of Central Leicestershire, Central Warwickshire, and Central Worcestershire, which may be looked upon as three local expansions of the naturally continuous N.E. and S.W. outcrop of the Keuper Marl series where it sinks below the continuous outcrop of the succeeding Rhaetic and Liassic formations.

The Keuper Marl area of *Central Leicestershire* gives origin to a fine rolling country. It is somewhat plain-like when contrasted with the higher grounds of the Archæan, Permian, and Lias, which overlook it on three of its sides; but some parts attain an elevation of 400 to 500 feet, and its highest points, marked by the towns of Hinckley and Market Bosworth, rise about 200 feet above the level of Leicester and Atherstone, which lie on its outer margins.

The Marl area of *Central Worcestershire*, on the other hand, may be defined as an almost level plain, some twelve miles wide, along the parallel of the city of Worcester, near its northern end, and narrowing to a point in the direction of Gloucester at its southern extremity. It is traversed by the lower course of the Severn from Martley to Tewkesbury and Gloucester. It is overlooked on the west by the long and steep range of the Malverns, and to the east by the Jurassic scarps of Brecon

and the Cotteswolds, which rise gradually to higher and higher elevations as they are followed from Droitwich to Cheltenham.

The central, and perhaps the most important area of outcrop of the Keuper Marls fills up much of *Central Warwickshire*, and occupies the country ranging S.E. from the city of Birmingham to Harbury, a few miles beyond Warwick. This is the district of the ancient *Forest of Arden*, and includes within its limits the towns of Henley-in-Arden, Redditch, Alcester, Solihull, Coleshill, Stratford-on-Avon, and others. It is crossed by the watershed between the basins of the Trent and the Severn, and is drained by the tributaries of the Avon and the Tame. Some parts of the area along the banks of these rivers are less than 200 ft. above sea level, and the central watershed is so low that it is crossed by the railway and canal routes at only about 150 ft. higher. Few parts of the area—with the exception of the broad meadow grounds of the Tame between Birmingham and Shustoke, and those of the Avon between Stratford and Tewkesbury—can be described as flat or monotonous. The surface is relieved by numberless long and broad ridges, often well wooded and highly picturesque. The highest of these ridges, which ranges from Moseley and King's Heath south of Birmingham almost to Henley-in-Arden, attains in some points a height of 600 ft. above the level of the sea, or more than 400 ft. above the level of the valleys of the Avon and the Tame.

Throughout the whole of their range in the Birmingham District the strata of the Keuper Marl group retain a fairly uniform lithological character. They consist of bright red marls and shales, with intercalated, thin-bedded, greyish sandy and micaceous shales, and occasional bands and seams of gypsum a few inches in thickness. In the Worcester, Warwick, and Leicester areas a thin grey sandstone group (the *Upper Keuper Sandstone* or *Shrewley Sandstone*) comes in near the summit of the series, but does not appear to be invariably present. It is exposed upon the sides of the canal near Shrewley, and elsewhere between Birmingham and Warwick, where it has yielded examples of fossil fishes (*Palæoniscus superstes*), the Crustacean *Estheria minuta*, and a few Lamellibranchiata (Brodie)—probably marine. Some of the same forms occur also in other localities. These Upper Keuper Sandstones are met with at many points around Henley-in-Arden, Alcester, and also near Inkberrow to the S.W. and near the town of Leicester to the N.E.

The marls of the Keuper, both above and below the horizon marked by the Shrewley sandstone, are everywhere barren of fossils. The division below this sandstone band is not only distinguished by the presence of layers of gypsum and occasional seams of grey sandy clay and marl (well seen in the brick-pits E. of Birmingham), but it contains in the Worcester District—between Droitwich and Stoke—a bed of rock salt, the brine from which

has for many years been pumped for the manufacture of salt at both these localities. In none of the remaining synclines of the district are actual salt-beds known, but pseudomorphs after salt are by no means uncommon in the strata.

Mode of Origin of the Triassic Rocks, etc.—This is not the place in which to discuss the various views which have been advanced by geologists to account for the remarkable lithological features of the Triassic deposits and for their peculiar stratigraphical relations to the Palæozoic rocks below. There can be no doubt that the rocky floor upon which the Triassic sediments of the Midlands repose must originally have been of very irregular outline, and of a very diversified surface. It was probably overlooked by tracts of high land along the Pennine Chain, Central Wales, Devon and Cornwall, and was relieved by steep and narrow heights in the neighbourhood of Charnwood Forest, the Lickeys, and the Mendips, and possibly in the earlier stages of the Triassic, by continuous high ground along this line. During the course of Triassic time the hollows in this irregular rocky floor became gradually filled up by the red sediments, the first to be deposited being the oldest Bunter formations in the deepest hollows to the west, while the succeeding Bunter and Keuper formations overlapped each other consecutively to the east farther and farther over the higher parts of the pre-Triassic floor. The lateral crust creep, which had ridged up the Carboniferous and older sediments of Britain in Permian time, seems to have continued almost to the close of the Bunter period, if, indeed, it did not extend far into the Keuper. Next, however, followed a period of comparative repose, in which the broader hollows were levelled up by the Keuper sediments, and the intermediate ridges became buried from sight. Eventually, at or near the close of the Keuper period, commenced that vast *regional* depression during which Britain and Western Europe were submerged below the waters of the Rhætic and Jurassic seas.

On the whole, it would seem that the facts discoverable in the Midlands tend to confirm the original views of Godwin-Austen and Professor Ramsay, that all the New Red Sandstones of the Midlands, including under that designation both the Triassic and the Permian, were deposited, as a group, under *continental* conditions. The rocky floor of this region was not only of most irregular form, but included at one and the same time the area from which the materials for the deposits were being denuded, and that upon which the deposits were being laid down. In periods of greatest depression the deeper hollows may have died down seaward into marine gulfs and bays, while landward they may have formed the floor of open river valleys, bounded by steep and rugged hill ranges. In periods of greater elevation, the entire region, or its larger valleys, may have enclosed land-locked lagoons and freshwater lakes, or formed one or many closed basins, the deepest tracts of which may have become overspread by inland lakes at one period, and at another by dried up salt-pans, surrounded by stretches of barren desert. The remarkable breccias of the Permian, the Pebble Beds of the Trias, the false bedded sands of the Bunter, the gypsum and brine beds of the Keuper, and the buried hills swathed in the red sandstone and marls are all incidents in one connected story, in which even the most diverse views with respect to the proper interpretation of the visible phenomena are not only of interest and of value, but may each and all contain a certain amount of truth.

Post-Triassic Formations.

As none of the formations of the district of later date than the Keuper Marls will be visited by the Geologists' Association in 1898, these formations, although they cover collectively a large proportion of the southern and eastern parts of the district, may here be dismissed in a very few words.

The *Rhætic* strata of the Birmingham District are everywhere present at the base of the Lias, and appear to be more closely allied petrographically to the strata of that overlying formation than to those of the underlying formation of the Keuper Marls. They are nowhere as much as 50 ft. in thickness. They are very rarely exposed, and the sections are usually very indifferent; perhaps the best is that afforded by the railway cutting at Harbury, where the local White Lias is seen, and there is a band of yellowish sandstone which has yielded *Estheria minuta*. Near Wootton Wawen, shelly limestones occur under the sandstone, and are rich in the usual Rhætic lamellibranchs. Rhætic rocks also occur in the neighbourhood of Leicester (Harrison). The nearest exposure of the Rhætic Beds to the City of Birmingham is that surrounding the small outlier of Lower Lias at Knowle, near Edgbaston, where the most conspicuous stratum is a yellow micaceous sandstone, with *Schizodus cloacinus* (Brodie).

The *Lower Lias* forms a terrace-like expanse of country about eight miles in width, ranging along the south-east edge of the district from Leicester to Stratford, and prolonged in three promontory-like extensions northward into the Keuper Marl area, that which lies east of Droitwich extending within a few miles of the town of Bromsgrove. The best sections of the Lower Lias are those of the railway cutting north-west of Harbury Station, and in the cement quarries of that place, at Rugby, Southam, and Jewbold. Fossils are locally abundant, and are well known through the classic researches of the late Rev. P. B. Brodie.

The *Middle Lias*, or *Marlstone* series, usually gives origin to a conspicuous scarp overlooking the low ground of the Lower Lias, and attaining its highest elevation in the district at Edge Hill. Some of its strata are locally quarried for building stone.

The distribution of the beds of the *Upper Lias*, and those of the Inferior Oolite is given upon Map No. 2 (p. 315); but they call for no further notice in this place.

NOTES ON THE PETROLOGY OF THE BIRMINGHAM DISTRICT.

By W. W. WATTS, M.A., SEC.G.S.

The Midland District will always be classic to the student of rocks because it is the ground where the veteran petrologist Allport began those investigations which he carried out with such success that his descriptions, although the earliest we have, remain unrivalled to this day as models of brief yet full and accurate delineations of rock-structure and composition. From the Wrekin to Charnwood, from Swinnerton Park to Rowley, and

from pre-Cambrian to post-Carboniferous rocks, he dealt with nothing which he did not thoroughly investigate, always drawing important deductions from his observations, and always searching for new facts and new methods to increase the utility of the microscope as an instrument of petrographic research.

In the few notes which follow I propose to give a short summary of the work of Allport, Waller, Rutley, and Teall,* adding here and there a few points which have come out from my own microscopic observations, founded on specimens collected by Professor Lapworth or myself, or by Mr. Walcot Gibson when he was re-surveying the Lickey Hills for the Geological Survey. I have also had the advantage of confirming many of Allport's conclusions from the study of a set of his own slides now in the possession of Professor Lapworth. It will be most convenient to take the rocks in topographical order, and to deal with the three chief areas of Nuneaton, the Lickey, and the South Staffordshire Coalfield.

THE NUNEATON DISTRICT.

(a) The Caldecote Rocks (Pre-Cambrian).

1. *The Tuffs*.—The composition of the rocks seen in the *Tunnel* near Caldecote Hill House and the old road above the "Anchor" Inn is andesitic according to Mr. Rutley, and basaltic according to Mr. Waller. The constituent lapilli are much decomposed, but on the whole I incline to the opinion that the contributing rocks were rather basic than intermediate, although neither olivine nor its pseudomorphs have yet been described in them. Quartz is not common, the dominant felspar is plagioclase, iron oxide is abundant, and the amount of chlorite indicates that a good deal of augite must have once been present in the magma from which the lapilli were derived. Mr. Waller describes lapilli of porphyritic basalt, which seem to correspond in composition and aspect with a porphyritic basalt to be immediately described.

2. *Quartz-felspar Rock* (Quartz-felsite of Waller; Quartz-porphry of Rutley).—This appears to occur rather high up in the Archæan series, as it is seen close under the basement rocks of the quartzite in Mr. Abel's quarry (Hartshill Grange), and it also occurs in the "Blue Hole," near Caldecote House. It has very much the appearance of a quartz-porphry in both localities, but no one has yet succeeded in finding it in a non-brecciated

* Allport, *Quart. Journ. Geol. Soc.*, vol. xxx, 1874, p. 520; vol. xxxv, 1879, p. 367.

Waller, *Geol. Mag.*, Decade 3, vol. iii, p. 322; *Midland Naturalist*, vol. vi, p. 26, 1885.

Rutley, *Geol. Mag.*, Decade 3, vol. iii, p. 557.

Teall, *British Petrography* (Dulau), London, 1888.

condition. In the latter locality the rock exfoliates into spheres, many of them being very large, and surrounded by similar material in a rotten condition. This aspect of the rock resembles the spheroid-bearing wacke which is so often produced by the weathering of basalt, and is so conspicuous a feature in the dolerite of Rowley Regis. The disintegrated state of the higher parts of the rock near the contact of the quartzite is suggestive that much weathering had taken place before the deposition of the latter rock, as this weathered condition only extends a few feet below the position of the basal beds of the quartzite, sound rock being met with at the bottom of the cutting. This state of weathering is interesting also in connexion with the phenomena to be immediately described.

3. *The Porphyritic Basalt* (dark basic rock of Waller; andesite of Rutley).—This rock forms a dyke which traverses the quartz-felspar rock at the entrance to Mr. Abel's quarry, while it also penetrates the quartz-felspar rock in the "Blue Hole," and appears to overlie it. The only porphyritic ingredient in the slides I have seen is plagioclase felspar (determined as labradorite by Mr. Waller) in well-formed crystals which are frequently aggregated together in groups. Mr. Waller has also detected occasional crystals of augite. The ground-mass is like that of an andesitic basalt made up of plagioclase microlites set amongst granules of augite (Rutley thinks this mineral is more likely to be hornblende). The microlites flow in streams round the phenocrysts and the rock has a very characteristic aspect. The grain of the ground-mass varies in fineness, and when at its coarsest an exceptional amount of chlorite, sometimes in good-sized patches which may be relics of augite crystals, is present.

4. *Mixture Rocks*.—Microscopic slides cut from the junction specimens of this rock with the quartz-felspar rock, proved to Mr. Waller that strings and threads of the basalt penetrated between the grains of the quartz-felspar rock in all directions. The basalt was the later rock and it forms at its junction an intimate mixture with the constituents of the already solidified and disintegrated quartz-felspar rock. When once this fact is recognised it becomes easy to comprehend the complicated relationships between the two rocks in the quarry in question. The result of Mr. Waller's studies, published in 1886, should not be overlooked by those authors (British and Foreign) who are now working on the mixtures of acid and basic rocks.

The Quartz-felspar rock consists of grains of quartz and both orthoclase and plagioclase felspar. The latter are well rounded, but there is no evidence that the rounding has been accomplished in water, for both minerals resemble whole or broken phenocrysts seen commonly in quartz-porphyrines, and the quartz exhibits stone cavities and rounded re-entrant angles as if partly re-fused in a quartz-porphyry magma and then broken up,

either by the disintegration and weathering of a solid mass of igneous rock or by ejection as fragments to form a tuff. I am inclined to think the latter is its real origin, as the rock consists almost entirely of quartz and felspar grains, with very few grains of true quartz-porphyry or its ground-mass in it. Fragments of a genuine igneous quartz-porphyry, however, are found in the succeeding Cambrian Quartzite, perhaps derived from this Caldecote series, as will be seen shortly. The quartz is slightly opalescent, and has a faint bluish tinge.

This disintegrated material was invaded by the basalt and swallowed by it so that for some distance from the junction its constituents are floated in the minutely microlithic ground-mass of the basalt. It is, however, noticeable that the proportion of iron-ore granules in the basalt has considerably diminished, and its porphyritic crystals appear to have been strained out, so that they are rarely present in the mixture rock and are only to be found in the largest basalt strings. In connexion with this point it is important that the porphyritic crystals are more abundant and evident along the junction plane than elsewhere, as was pointed out to me by Prof Lapworth.

The peculiar netted or honeycombed aspect of the quartz in this rock has been noticed by Mr. Waller in his paper.* "I think I have detected a quartz grain in the act of breaking up. It is of irregular shape, and at one side is covered with a network of strings of minute fluid cavities which divide it into roughly polygonal portions. As we pass to the other side of the crystal, however, these become lines of an infiltrated green material, and at the extreme edge a few of the polygonal fragments are quite detached, and separated from the main mass by portions of the ill-defined ground-mass which occurs in this particular specimen." This is fully borne out by the slides which I have examined. The network tends to be hexagonal in the majority of instances, and in the different parts of a single grain the polygonal pieces can be seen to turn more or less on their axes and eventually to become slightly detached, and then to float off into the basalt matrix. In a few instances the quartz is traversed by parallel planes, along which disintegration begins, and is completed by the formation of a series of cross-fractures. Whether these structures were present in the original grain, or were developed for the first time by the intrusion of the basalt, I cannot say, but the separation and brecciation were certainly due to the violence of the basalt intrusion. In parts of the rock the final result of the action has been the complete shattering of the quartz, which is then embedded in very tiny particles in the abundant basaltic magma. The rounded, turbid, felspar granules are generally clear and bleached at their margins.

It may be mentioned here that a precisely similar polygonal

* Waller, *loc. cit.*, p. 324.

hexagonal) structure is well seen in the porphyroids of Peldar or in Charnwood Forest.

Whether the basalt in the Blue Hole is of the nature of a lava or an intrusion has not been precisely determined, but two points are in favour of the latter interpretation. A definite dyke of the rock is found to pierce the quartz-felspar rock in the more recently opened section of Mr. Abel's quarry, and the action of the basalt on the latter rock in the Blue Hole has been of a violent mechanical character. The act of intrusion, however, seems to have been deliberate, for the basaltic matrix contains well-defined patches of a substance indistinguishable from itself; it would seem from this that the basalt may have solidified in places, and then been broken up and involved with the quartz and felspar fragments in later injections of identical material.

(b) The Cambrian Rocks.

5. *The Quartzites*.—The basement beds of the Hartshill Quartzite are of great interest from the fact that, for a considerable thickness, they contain abundant fragments, varying from a pin's head to a pea in size, derived from the underlying Caldecote Rocks. But certain bands are conglomeratic, and consist of pebbles ranging from those not larger than a sparrow's egg up to boulders 3 ft. in length. These are generally sub-angular, and most of the known varieties of the Caldecote Rocks have been recognised in them, as well as several other varieties of rocks not at present known from that series.

Quartz grains are always plentiful, and they are generally rounded. Many of them show the polygonal network or parallel cracks and various stages of brecciation. It is, however, clear, that the brecciation and re-cementation have been accomplished previously to the rounding and embedding of the grains in the Quartzite, thus giving additional support to the suggestion that they may have been derived from the quartz-felspar rocks which underly them. When a sufficient number of clean quartz-grains occur in close proximity, secondary growth of silica in optical continuity has taken place, similar to that in the quartzite beds above and below. Rounded felspars and grains of felsitic rock are especially common in the lower bands, and in one specimen there are several grains of quartz-porphyry containing phenocrysts of quartz, which, though rounded, never show the polygonal network, parallel structure, or brecciation. Chips of basic rock are also present in these fine-grained rocks, but it is not possible to say with any certainty that they correspond with the basalt of the Blue Hole.

The boulder beds of the Quartzite yield abundant fragments of a quartz-felspar rock macroscopically indistinguishable from that of the Blue Hole. Fragments of fine and coarse tuff are also

common, and one fragment, which was examined microscopically corresponds very well with that described from the Caldecott series by Mr. Waller.* It contains abundant felspar in an altered state, a few quartz fragments, lapilli of quartz-felsite, and many lapilli composed of a green rock apparently basic or intermediate composition. Another fragment consists of much decomposed porphyritic basalt. The porphyritic felspars are similar to those in the basalt of the Blue Hole and of the dyke in Mr. Abel's quarry, and they are similarly grouped. Although the ground mass is obscured by decomposition it is a marked "mikro-lithenfilz," like that of the dyke in the Archæan rocks. The main difference from the Archæan specimens that I have hitherto studied is that it contains rather a larger proportion of chlorite and delessite pseudomorphs after augite, but in this character it comes rather nearer to the dyke in Mr. Abel's quarry than to the rock of the Blue Hole.

The higher beds of the Quartzite were described by Mr. Rutley. The growth of new silica appears to have occurred freely throughout the rock, especially in its purer portions, thus probably accounting for the high crushing strength of the rock. Grains of glauconite are frequently to be seen in the higher beds, particularly in those associated with the Hyolite Limestone.

6. *The Diorites.*—These rocks have been so admirably described by Allport and Teall, and figured by the latter from Allport's original slides, that there is not much to add to the descriptions. Porphyritic olivine is frequently present in unmistakable crystals, which, however, are always in the form of pseudomorphs. Hornblende is rarely well preserved in surface specimens, but in those obtained by deep quarrying it is fresh and brown in colour. Augite tends to be a porphyritic ingredient, but felspar is rarely porphyritic, although the crystals are frequently large; orthoclase as well as plagioclase is present. The order of crystallisation is not constant. Olivine, when present, has usually crystallised first, followed by augite when the latter is present. In many varieties, like those of Marston Jabet, the hornblende occurs in idiomorphic crystals, which are usually elongated, and the long needles can sometimes be seen in hand specimens, as at Tuttle Hill. On the other hand, at Atherstone and Griff Hollow the structure is ophitic, and plagioclase crystals are embedded in large plates of hornblende. (See Teall, *op. cit.* Plate xxix.)

Apatite is a frequent constituent, and sometimes a ground mass of calcite and chlorite is present. This is not usually abundant, and the rocks have frequently the idiomorphic texture of the lamprophyres. Indeed, the association of the minerals, the frequent substitution of augite for hornblende, the common idiomorphism of the latter mineral, the infrequency of porphyritic

* *Loc. cit.*, p. 323.

spar, the entire absence of quartz, and the somewhat basic composition of the rocks, all coincide in suggesting that a group of rocks which here and elsewhere occurs so exclusively in normal sill-like dykes should be placed in the dyke-rock family, led by Rosenbusch *Lamprophyres*. If this suggestion were adopted, the rocks would be appropriately called hornblendic, gitic, or olivine-bearing *camptonites*. The occurrence of mica in rocks of this class is not common, and the entire absence of mica in the area is deserving of remark.

Two varieties of these rocks are deserving of special attention. At Chilvers Coton it is noted by Allport and by Rutley that felspar comes scarcer than usual, and the first observer describes a variety which consists mainly of hornblende. One of Allport's specimens from Griff Hollow is becoming patchy, being made in places of hornblende with few felspars embedded in it, and in other places of crowded felspars. Associated with the hornblende there is a colourless tremolite. This patchy character comes extreme at Chilvers Coton railway cutting, as mentioned by Allport. A specimen collected by myself from this locality several years ago is practically a *hornblende-picrite*, consisting most wholly of brown hornblende and colourless tremolite, the latter possibly pseudo-morphic after olivine.

A very peculiar variety of the Diorite, forming dykes or sills foot or so thick, has been discovered by Professor Lapworth penetrating the basal Quartzites in Mr. Trye's quarry (the Anchor quarry); the variety has been named by him *anchorite* as a convenient field term. The rock looks and breaks like a conglomerate in which rounded masses of a purple diorite or melaphyre are embedded in a white matrix. On microscopic examination the "pebbles" prove to be spheroids of diorite, in which there is an abundance of idiomorphic hornblende much decomposed. These spheroids are embedded in fine-grained veins which consist chiefly of felspar, some being certainly orthoclase; associated with this is a highly refractive mineral with low birefringence which appears to be zoisite. A little iron-ore is also present in the veins, together with a small amount of interstitial matter in which very narrow, long, microlites of felspar occur. Clearly the rock is of igneous origin, and is an abnormal combination of spheroids and contemporaneous veins resulting from segregation of the magma into basic clots and acid veins.

The rock-type represented by the Nuneaton Diorites is a widely disseminated one. Whenever Stockingford Shales have been penetrated by deep borings, they are found to be pierced by sills of this rock. A similar rock is intrusive in the Archæan rocks of the Lickey, in the Shineton Shales of the Wrekin, in the rocks of the Longmynd itself, and its northern continuation at Layston Hill, near Shrewsbury, and they are known to pierce the Cambrian rocks in other localities. Similar rocks are intru-

sive in the Cambrian Quartzites and Limestone of Inchnadamff,* and a hornblende-picrite like that of Chilvers Coton occurs amongst the Bray Head Rocks, at Greystones,† in Ireland. In none of these localities are the rocks known to penetrate any formation of later than Cambrian age.

THE LICKEY HILLS.

The Lickey Quartzite has been figured by Teall‡ and described by several authors, but so far as I am aware the only petrological description of the underlying Barnt Green Rocks hitherto published is contained in the Summary of Progress of the Geological Survey for 1897, just published. From the brief description of the rocks founded on my own notes and published therein, I extract a few notes by permission of Sir Archibald Geikie. The specimens were collected by Mr. Walcot Gibson during his re-survey of the area, and such field notes as occur in what follows are due to him, and, as will be seen by comparison with the notes on pp. 328-330, the microscopic observations agree with the conclusions drawn by Prof. Lapworth some years ago from the field evidence.

1. *The Barnt Green Rocks.*—These are chiefly pyroclastic rocks though some of them consist of pyroclastic material which has been deposited in water. § “The pyroclastic rocks are mostly tuffs made out of fragmental felspars, amongst which orthoclase predominates over plagioclase; there are also fragments of an orthophyre-like rock. Quartz fragments are practically absent from the typical tuffs, but when the felspars begin to be rolled and rounded as well as broken, and the tuff has evidently been laid down in water, a little quartz is generally present. One example, which may be called a volcanic grit, such as may have resulted from the wearing down of lavas and tuffs,” or from the dropping of the material of orthophyre-tuff in water, “contains more grains of ferro-magnesian minerals as well as particles of orthophyre and orthophyre-tuff. The ground mass of all these rocks appears to have undergone silicification. Many of the rocks have been shattered,” by earth movement, “and filled with veins of calcite and quartz.” One of the rocks, rather more massive than the rest, has somewhat the appearance of an intrusive mass in the field, but “the microscopic character of the rock, while not disproving this supposition, lends it no additional support, for the rock does not differ in any marked degree from those described as orthophyre-tuffs, except that it is finer-grained, and the large and obviously clastic felspars are absent. A dark purplish-blue shale from this group is well laminated, and

* Teall, *Geol. Mag.*, Dec. 3, vol. iii, 1886, p. 346.

† Watts, *Rep. Brit. Assoc.*, 1893, p. 767.

‡ “British Petrography,” Plates xlv and xlvi.

§ *Op. cit.*, p. 68.

contains angular grains of quartz, felspar, and white mica embedded in an opaque ground-mass. A set of plagioclase-bearing igneous rocks penetrates the Barnt Green Group. The only original minerals left are plagioclase and iron ores, the former are arranged as in an ophitic rock; the secondary minerals, chlorite, serpentine, and epidote, do not make it clear whether the original ferro-magnesian mineral was hornblende or augite, but the general likeness in structure and appearance, to the diorites [camptonites] of Nuneaton, suggest that the rocks should be classed with the diorites. They have not yet been found to penetrate the quartzites. Another igneous rock is a brecciated porphyritic basalt, which may be an intrusion or a lava-flow, but the field evidence does not appear to be sufficient to decide the question." This last rock is somewhat like the porphyritic basalt which occurs in the "Blue Hole" at Caldecote.

2. *The Quartzite*.—"The main constituent is quartz in rolled grains, round which new quartz has been deposited in optical continuity, so that the constituents of the rock are now closely interlocked. Many of the varieties are rich in grains of felspar, and a few grains of glauconite are to be found in most of them. This last fact is suggestive, when it is remembered that the Hollybush Sandstone (Comley Sandstone), which in Shropshire overlies the [Cambrian] quartzite, is rich in grains of glauconite. Traces of bedding are generally to be seen [even in microscopic slides], and there is no evidence of crushing in the mass of the rock, although the slicken-sided surface of some of the joint-planes indicates that considerable movement must have taken place." The secondary silicification of the rock reaches its highest degree where the movement has been considerable, and it is from such localities that the specimens of quartzite usually figured and described from the area have been taken.

THE DOLERITES AND BASALTS OF THE SOUTH STAFFORDSHIRE COALFIELD.

In very numerous localities in England, Ireland, and Scotland there occur intrusive basic rocks of later date than the greater part of the Coal Measures, and the South Staffordshire Coalfield is no exception. Intrusive sills are found throughout the field, and in those places where the sills are thick and massive the rock becomes coarser-grained. Rowley Regis is the largest mass of dolerite in the Coalfield, and it is a laccolite intruded into the southward continuation of the Dudley anticline. The cover has been entirely removed, and the mass is now only in contact with its sole. Other large masses appear at the surface at Barrow Hill and at Pouk Hill, near Walsall. The sills occupy a good deal of the surface of the ground near Wednesfield. These rocks formed

a portion of the subject of Allport's memoir on the British Carboniferous Dolerites.

Porphyritic olivine is almost invariably a constituent of the rocks ; it is frequently quite fresh, but in surface specimens it is often converted into pseudomorphs of serpentine, calcite, or zeolite, with or without specular iron. The original discovery of the nature of these changes by Allport has had a wide-reaching effect on our knowledge of the serpentine rocks. Augite is a still more abundant constituent ; it is generally coloured, pale brown, yellowish, puce-purple, warm-brown, or green tinged, and is frequently slightly pleochroic. Indeed, it is the variety of augite supposed to be titaniferous, a supposition which, I believe, has never been verified. Plagioclase felspar is very abundant, and orthoclase occurs sparingly in many varieties. Magnetite and ilmenite are both of common occurrence, and in the coarser varieties apatite occurs. Hornblende is of rather rare occurrence. In most varieties, but especially in the coarser types, interstitial zeolites are to be found, and in some examples there are not less than three distinct zeolites, of which analcime appears to be one.

The structure is very variable. At Pouk Hill the rock is ophitic, but patchy, and there would not appear to have been any very considerable interval between the crystallisation of the felspar and that of the augite. At Rowley microporphyritic rocks are common, plagioclase, orthoclase, and olivine occur as phenocrysts in a ground-mass composed of idiomorphic, rod-like, augite, and crystalline magnetite, embedded in felspar. At Hailstone Hill, part of the Rowley mass, a very beautiful, coarse-grained rock is occasionally met with which at once attracts attention from the large six-sided plates of ilmenite found in it. The felspars are large and well-formed, and often include small augites, while larger crystals of augite, well-formed and idiomorphic, are frequently found outside them, and embedded like them, in interstitial matter. Olivine is present, and the plates of ilmenite appear in the slides as rods or blotches. Apatite is usually abundant. While the order of crystallisation in the Rowley Rag is generally the reverse of that usually found in dolerites, Allport found specimens in which the relationship of augite and felspar was that of a micropegmatite (or a variety of centric structure), the two substances crystallising simultaneously so that large areas of each polarise together. Allport also discovered and briefly described a set of remarkable red contemporaneous veins from Hailstone Hill, which were subsequently more fully dealt with by Waller.* These consist chiefly of orthoclase felspar, as shown by the twinning and the refractive index, with sparingly distributed green augite and magnetite, set in inter-

* *Midland Naturalist*, vol. viii, 1885, p. 261.

stitial matter in which Waller recognised colourless glass. A brown fibrous zeolite also occurs interstitially, and to this the colour of the veins is apparently due. Mr. Waller's analysis of the veins shows that they contain 58·3 per cent. of silica, 5·9 of potash, and 5·2 of soda, as against 48·8, 1·9, and 3·7 respectively in the normal rock. The veins have a specific gravity of 2·58, while the normal rock gave Mr. Waller a specific gravity of 2·79. A specimen tested by myself gave 2·76 for the normal rock, and 2·78 for the coarse ilmenite-bearing rock previously described.

In an old quarry near the north-east side of the mass a very beautiful columnar structure is revealed, and in one of the great excavations at Rowley itself the columns are singularly starch-like, although of very large size. Spheroidal structure is very common, the spheroids being enclosed between more or less rectangular joints in the same fashion as is seen in perlitic texture. An excellent example, which Prof. Bonney has made classical, is figured by him from Turner's Pit, and the original of his drawing appears to be still visible.* The weathering of the basalt has already been remarked on, and it extends deep into the mass, reducing it to a sandy-looking product, in which are embedded the more durable of the spheroids, the outer layers of which, when partly rotted, form shaly-looking "brows" round the augen-like spheroids.

The smaller sills are of finer-grained basalt, known as green rock by the coal-miners, which passes readily into white trap near the contact with coal-seams.

All these rocks in South Staffordshire and similar rocks at the Titterstone Clee in Shropshire, in Leicestershire, and elsewhere, are intrusive into the upper Coal-measures, and so cannot be of earlier date than very late Carboniferous. A very similar rock was described by Allport, at Swinnerton Park, near Trent-ham, in North Staffordshire, and Kirkby† has shown that it is a dyke intrusive into the Trias. If all these rocks are of the same age, the date of intrusion must be post-Triassic.

But Jukes, in his *Survey Memoir on the South Staffordshire Coalfield*, points out that the Rowley mass partakes in the movements which have affected the Coalfield, thus placing an upper limit to the age of the intrusion if the date of the movement can be ascertained.

A comparison of the dolerites with the well-known Tertiary lavas of Antrim, and with the abundant Tertiary dolerite dykes which occur all over the North of Ireland, in Scotland, the Isle of Man, and elsewhere, shows that there are many features in common between the two types. The character, colour, and pleochroism of the augite, and the inconstant relation of the two

* Bonney, *Quart. Journ. Geol. Soc.*, vol. xxxii, 1876, p. 151.

† Kirkby, *Trans. N. Staffs. Nat. Field Club*, vol. xxviii, 1894, p. 129.

chief constituents are characters linking the two types, while the freshness of many of the minerals, and especially of the olivine, gives the rock a very new aspect. It would be scarcely possible for a petrologist to discriminate the coarse varieties of rock seen at Hailstone Hill from that of Killala Bay, in Sligo, on the one hand, or from the coarse dolerites of Portrush and Fair Head on the other.* Again the finer grained dolerite lavas of the Giant's Causeway, and the Tertiary dykes of Lisnaskea and elsewhere in Ireland would be very difficult to distinguish from the normal rocks of Pouk Hill and Rowley.

When we recollect that some of the faults which bound the South Staffordshire Coalfield traverse Jurassic rocks, one is tempted to ask whether it may not be possible that those movements which post-date the Rowley Rag in the South Staffordshire Coalfield are in reality of Tertiary date. If not, the similarity of pre-Tertiary and post-Tertiary volcanic rocks is closer even than Allport suspected, when he was struggling for a recognition of the identity of the rocks of these different ages.

THE ANCIENT GLACIERS OF THE MIDLAND COUNTIES OF ENGLAND.

BY W. JEROME HARRISON, F.G.S.

As far as their glacial phenomena are concerned, the Midland Counties offer to the geologist one of the most interesting and important fields of research in the British Isles. And this for three main reasons :

- (1) Three great glaciers met here.
- (2) The district contains examples of the terminal and lateral moraines, and also of the "fringe"† of these glaciers.
- (3) But little detailed work has as yet been done in mapping out the precise courses and limits of the great streams of ice by which the district was formerly invaded.

NO SUBMERGENCE.

It may be said at once that there is no evidence in the Midlands of any great depression since the close of the Mesozoic Era. The so-called "sea cliffs," "coast lines," etc., can be shown to be but the ordinary results of sub-aerial denudation; the finely-stratified, often false-bedded, gravels, sands, and loams of the surface deposits are for the most part the results of the sub-glacial, englacial, and supra-glacial drainage-systems of the glaciers. Some loams were deposited in ice-dammed glacial lakes, while

* *Guide to the Collections of Rocks, etc., belonging to the Geological Survey of Ireland.* Dublin, 1895, pp. 51 and 78.

† I apply the term "fringe" to the dubious region which lay just at or in front of the original margin of the ice. It is usually occupied by gravels and sands, the results of the melting of the ice. The glacier-ice sometimes made temporary excursions into the "fringe" in some regions, but it was never permanently glaciated.

Extensive sheets of gravel were formed along the "fringe," especially at the time of the final disappearance of the ice. The broken and fragmentary sea-shells which have been found in some sections never lived where they now occur, but were scraped off the bottom of the Irish Sea by the advancing ice.

Of the earlier deposits formed by the old rivers, which appear to have crossed the Midlands from west to east during Tertiary times, only scanty traces remain. They were largely interfered with, and destroyed or covered up by the action of the glaciers.

LOCAL ICE.

During the Glacial Period several of the Midland hills—such as Charnwood Forest, the Rowley Hills, the Hartshill Range, etc.—appear to have been permanently capped by ice. This ice enabled them to more or less successfully resist the invasion of foreign ice, which consequently glided round them. The result is that we find little or no foreign drift upon the summits of these hills, although each such elevation has a stream or tail of boulders, which can be traced proceeding from it to the southward. And the upper portion of the glacial ice—by which alone these hill-tops would in any case be traversed—would be comparatively "clean" ice, containing but little *débris*.

THE THREE GREAT GLACIERS WHICH INVADED THE MIDLANDS.

There is clear evidence of the entrance of "rivers of ice" (glaciers) into the Midlands from at least three external sources.

These glaciers may be named :

- (i.) The Arenig Glacier.
- (ii.) The Irish Sea Glacier.
- (iii.) The North Sea Glacier.

I. THE ARENIG GLACIER.—The Arenig Hills of North Wales lie south-east of Snowdon, and attain a height of 2,817 ft. They are very favourably placed to arrest the south-west winds, and the precipitation of snow upon them during the Glacial Period must have been enormous. There is the clearest evidence that a glacier descended eastward from the Arenigs, passing down the Vale of Llangollen and debouching into the Shropshire plain near Ruabon, Overton, and Ellesmere. Great moraine heaps occur here. The Welsh ice then pursued a south-easterly course across Shropshire and Staffordshire, and terminated its career in the tract of country lying between Bromsgrove and Birmingham, some of its boulders (felspathic Arenig ashes and felsites) occurring on the top of Romsley Hill (one of the Clent Hills, in North Worcestershire) at the remarkable elevation of 897 ft.

This Arenig Glacier presents several remarkable features, and

appears to have retained the characteristics of a true "Alpine"-type glacier throughout its course. It did not follow what might have been thought its normal course on emerging from the Vale of Llangollen, either along the present Dee Valley to the north, or the Severn Valley to the south. The former was blocked by the Irish Sea ice; while Welsh ice from Plinlimmon, the Malverns, etc., occupied much of the Severn Valley to the south.

The Welsh ice had, as we know from many sections on the coast of North Wales, attained a considerable extension *before* the arrival in its district of the Irish Sea Glacier. It is thus probable that the Arenig Glacier was the *first* of the three great glaciers mentioned above to enter the Midlands. But it is doubtful if it would have obtained the extension which it actually did (the distance from Bromsgrove to the Arenigs is about 100 miles), or if its boulders would have attained the remarkable height on the Clent Hills of 897 ft. had it not been for the extraneous impelling force which its ice received from the ice of the Irish Sea Glacier, which must have united with the Welsh Arenig ice and forced it onward and forward.

Welsh boulders (often accompanied by basalt boulders from the Rowley Hills) occur along a line about 15 or 20 miles in length, extending from the south-west of Bromsgrove to the north-east of Birmingham. But this indicates a comparatively small amount of "fanning-out" as compared with the length of this glacier.

A fine Arenig boulder lies in Cannon-Hill Park, Birmingham, close to the spot from which it was dug out (Fig. 12). During the excursion to the Lickey Hills several Arenig boulders will be noted near Rubery, and a fine group of similar boulders lies close by upon till capping Frankley Lower Hill. At this point is the section which revolutionised the ideas of the late Prof. Carvill Lewis, when he visited it not long before his death.

There is also a classical section of the till, gravels, etc., of the Arenig Glacier exposed in the brickyards at California, a spot about four miles south-west of Birmingham. And the railway cutting at Moseley (a southern suburb of Birmingham) shows a magnificent section of false-bedded sands and gravels, 80 ft. in thickness, constituting an esker and probably marking an important point of discharge of the waters draining the glaciers which lay to the north-west (Pl. XII, Fig. 2).

The railway cuttings excavated in recent years at Soho, King's Norton, etc., near Birmingham, have revealed extensive sections of boulder-clays containing Welsh rocks. But in no case has any trace—not even a fragment—of a shell been found. The reason evidently is, that the Arenig Glacier *did not cross any portion of a sea bottom* during its course from Wales to Birmingham. The Keuper Sandstone at Weoley Castle (near the California brick-pits) showed striations running south-west; and the Bunter Sandstone ridge, adjoining Icknield Street, Birmingham, bears



along its course the signs of enormous ice pressure acting from the north-west, which has forced Arenig boulders into the sandstone, and torn off great slices from it.*

The Rowley Hills (highest point about 890 ft.) of South Staffordshire lie directly in the path of the Arenig Glacier. I have found no foreign drift upon their summits, but a train of basalt boulders can be traced from them to the south and east, extending to the Clent Hills, to Harborne, and to the north-western suburbs of Birmingham. Where the surface soil on the Rowley hills has been removed during quarrying operations, well-striated platforms of the basalt have been exposed, the striations running from N.W. to S.E. The general contour of these hills is that of a great *roche moutonnée*.

II. THE IRISH SEA GLACIER. — The ice from the South of Scotland, uniting with the Lake district ice and with ice from Ireland, advanced southwards during the Glacial Period until it completely filled the basin of the Irish Sea, and overrode the highest summit (Snæfell, 2,024 ft.) of the Isle of Man. Passing southwards, this great body of ice received such a stout resistance from the mountains and glaciers of North Wales that it was divided into two great lobes. The western lobe passed on down St. George's Channel, while the eastern lobe swept over Lancashire and Cheshire, and then, invading Shropshire, Staffordshire, and the adjacent counties, came to its final melting point along a line which has not as yet been precisely mapped out, but which is roughly indicated by great concentrations of boulders at such points as Much Wenlock, Burton, Bridgnorth, Enville, Wolverhampton, Bloxwich, Cannock Chase, Lichfield, and Rugeley.

The western lateral moraines of this grand glacier lie on the eastern slopes of the Welsh hills, as at Hope Mountain, Halkin Mountain, "the Gloppa," etc., ranging up to 1,400 feet; while its eastern moraines range up to a similar height on the western flanks of the Pennine Range.

The boulders brought by this Irish Sea glacier lie in amazing numbers at the places mentioned above in South Staffordshire and Shropshire, and can be traced thence northwards through Cheshire and Lancashire.

Lake district rocks—such as granites from Buttermere, Eskdale, Syning Gill, etc., with andesites, volcanic ashes, etc.—are most plentiful (as might be expected) on the *eastern* side of the district, where Mountain limestone and Carboniferous sandstone boulders also abound; while Scotch rocks — Criffel granites, etc.—are commoner on the west. But there is much intercrossing of these rocks, as might naturally be expected when we consider the changing conditions which affected the growth and progress of this Irish Sea Glacier.

See Dr. Crosskey's paper in *Proc. Birm. Phil. Soc.* vol. iii, 1883, p. 209.

Recent marine shells—usually in a very fragmentary state—have been found at several points in the path of the Irish Sea Glacier, as at Wolverhampton, Bushbury, Ketley, Lilleshall, Madeley, Worcester, etc.; not to mention the many points at which such shells have been found further to the north and west. These shells appear to have been scraped by the ice from off the bed of the Irish Sea.

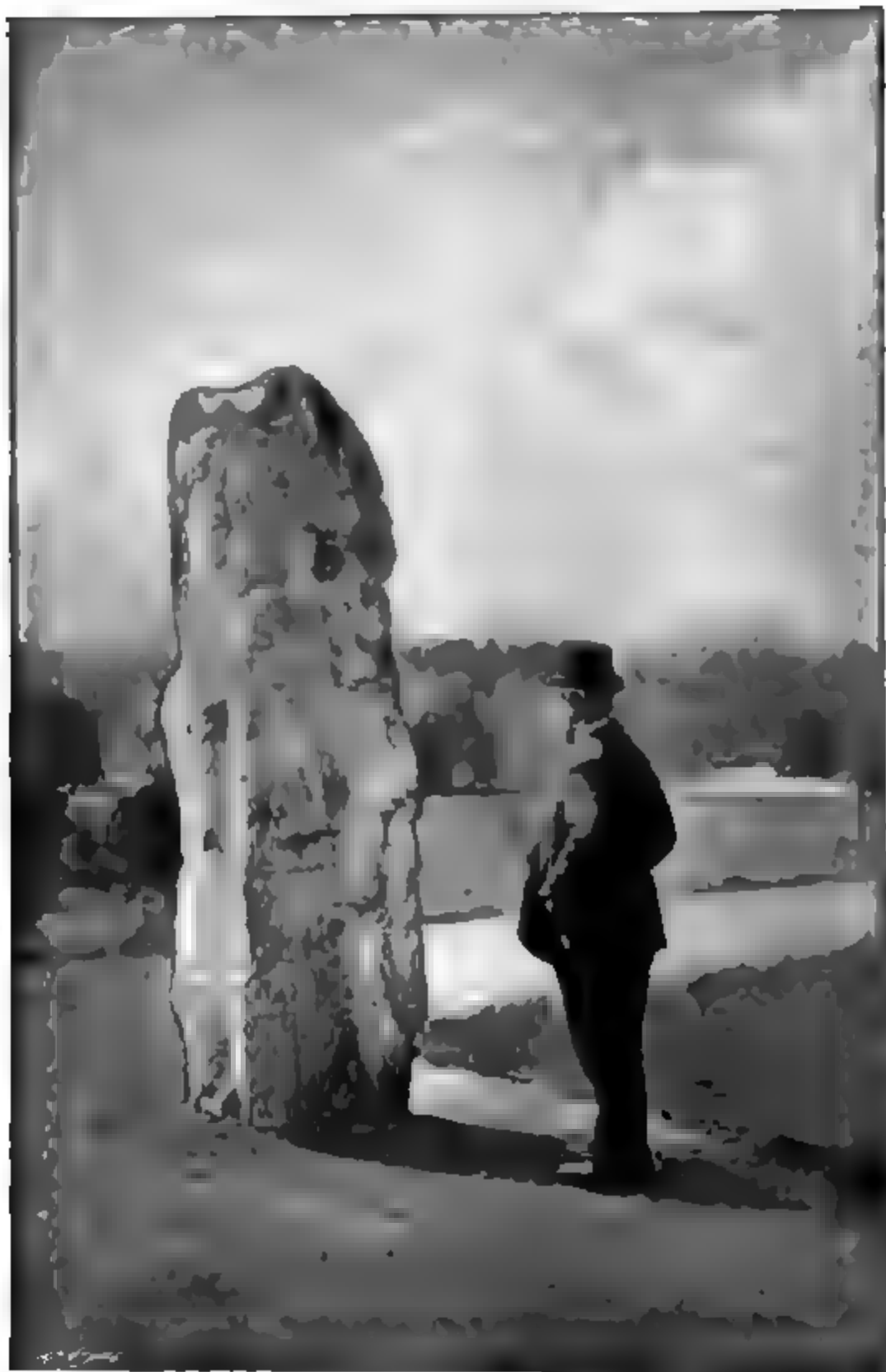
The tract of country extending from Wolverhampton by Trescott, Trysull, and Seisdon to Enville, may be described as an open-air petrological museum on a grand scale, but devoid of arrangement! Here rocks from the Lake district are mingled with the Kirkcudbrightshire granites of the South of Scotland, while an occasional "Welshman" tells that we are on the Arenig "trail." In Wolverhampton Park a grand boulder of Lake district (?) andesite over eleven feet in length is reared up like a monolith (Fig. 13), while close by a fine mass of grey Criffel granite bears it company. To the north, west, and south-west of Wolverhampton the erratics are to be numbered by the thousand, and some of them bear striations which they probably received while still *in situ*, and before removal from their native places. About thirty or forty years ago Mr. Mander, of The Mount, Tettenhall, Wolverhampton, preserved many fine local erratics from destruction by removing them to his grounds, where he formed them into a "bouldery."

III. THE NORTH SEA GLACIER. — This name seems preferable to that of "Scandinavian Glacier," which is frequently used. For both Scotland and the North of England contributed largely to the mighty mass of ice of which this glacier consisted; and there is also evidence to show that at some period of its history this glacier—or its southern part—crossed to England, not direct from Scandinavia, but by way of Holland and Denmark.

The foreign portion of the ice of the North Sea Glacier impinged upon the English coast just north of Flambro' Head, and it filled the basin of the North Sea down to the mouth of the Thames. Passing over the Lincolnshire Wolds it left much of its *débris* on the eastern side of these hills; but it took up a new burden from the chalk, and in its further course over East Anglia and the Midlands its characteristic deposit is known as the "Great Chalky Boulder-Clay."

Crossing the Trent near Gainsborough the ice pressed up the valley of this river past Nottingham and Derby to Burton-on-Trent. Here it came quite close to—if not into actual contact with—the Irish Sea Glacier. No section here shows clearly the relations of the respective boulder-clays of the two glaciers, but the ice from the east appears to me to be the later arrival.

Charnwood Forest formed a buttress which offered a stout resistance to the passage of this ice from the north-east. Twenty



(Copyright)

FIG. 13.—BOULDER IN WOLVERHAMPTON PARK.
(From a Photograph by W. Jerome Harrison. Block lent by
Messrs. Black & Co.)

years ago I described* the fine section then exposed on the flanks of Mount Sorrel, where the Chalky Boulder-Clay lay upon the striated and mammillated granite. Pressing down the Soar Valley the main body of the ice passed by Leicester† and Rugby to Buckingham, and thence its margin can be traced through Hertfordshire to the northern heights of London (Finchley, etc.), and eastwards still to Romford and South Essex.

A lobe of ice crossed South Leicestershire and entered the Avon Valley. The district immediately to the south-west of Charnwood, in N.W. Leicestershire and N. Warwickshire, has no foreign drift, but it was surrounded in such a way by ice-dams and high land that a considerable lake was formed in N.W. Leicestershire, extending from Hinckley to Market Bosworth and Ashby-de-la Zouch. [As Bosworth Field stands on a part of this old glacial lake-basin, it might, perhaps, be called "Lake Bosworth."] The loams of this lake are well shown in the brick-pits at Hinckley, and lying upon them are a few syenite boulders from the South Leicestershire Hills (Stoney Stanton, etc.), carried by bergs detached from the ice-front. The members of the Geologists' Association will have constant views during their two days' work in the Nuneaton district of the area once occupied by this old lake lying between the Hartshill Range and the Charnwood Hills. At Nuneaton a few years ago the Trias marls in a brick-pit exhibited a typical section, showing the reversal of the marl-beds (producing the typical "hook-form") due to the passage of ice, apparently a local glacier pressing southwards from the Hartshill Range.

CONCLUSION.

It is not possible to mention here more than a few of the principal conclusions to which I have been led during a study of the glacial deposits of the Midlands during the past thirty years; and it is quite impossible to give the evidence and the arguments by which these conclusions may be supported. But to the points mentioned above I may add:

(a) The district affords no proof of any "interglacial" period.

(b) The glacial deposits tell of one continuous but not unvarying period of cold, during which fluctuations of the ice-front took place.

(c) The freshness of the glacial deposits, and the small amount of denudation to which they have been subjected, show that no long period of time (probably not more than 10,000 years) has elapsed since the close of the Glacial Period.

(d) No exact divisions of the drift-beds can be made out; indeed it is probable that no two sections which are more than a few yards apart ever reveal exactly the same sequence.

* "Geology of Leicester and Rutland," with photographs. J. and T. Spencer, Leicester.

† When the railway between Leicester and Wigston was widened in 1874, a section more than a quarter of a mile in length was exposed, showing a beautifully striated pavement of Lias Limestones, covered by the Chalky Boulder-Clay.

There is evidence, however, that at the bottom of the drift-deposits we usually find :

(1) A bed of—it may be a tough reddish or bluish clay (= till), or even a mass consisting mainly of sand mixed with stones, whose compactness is due to the passage over it and pressure upon it of some heavy body (= the glacier-ice).

Above this till we often find (2) sandy and gravelly beds, generally false-bedded, caused by the drainage-system of the glacier, and deposited by water running either *under* the glacier, or *through* the glacier (in pipes or tunnels in the ice), or *upon* the glacier.

Finally, we often find (3) an upper, looser, and more incoherent deposit of clay, stones, etc., consisting of material contained in and upon the ice, which settled down during the final melting of the glacier.

This arrangement corresponds with the three-fold division of the drift into Upper and Lower Boulder-Clays with the intervening "Middle Sands and Gravels," which has so often been described elsewhere. But any one, or even two, of these divisions are as often absent as present ; and it is only by accident if the various deposits in any two sections are of exactly the same age.

LITERATURE OF THE MIDLAND DRIFT.

The *Proceedings of the Birmingham Nat. Hist. and Phil. Soc.* for 1895 contains a "Bibliography of Midland Glaciology," by W. Jerome Harrison, vol. ix, pp. 116-200, in which the titles (and an abstract of each paper) of more than 150 books and papers are given. From these the following may be selected :

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SUMMARY OF THE HISTORY OF GEOLOGICAL RESEARCH AMONG THE ROCKS OF THE BIRMINGHAM DISTRICT.

This paper has been drawn up mainly for the use of those geologists who took part in the Long Excursion of the Geologists' Association in 1898. Consequently, while it includes a general sketch of the geology of the district as a whole, only those geological formations visited by the members during the Excursion have been treated of at length. But since those formations of which least is known—where discovery is still in progress, and where opinion for the time being is necessarily divided—are of the greatest interest to outsiders, these have been noticed in fuller detail, while the better known formations have been but briefly touched upon.

The history of Geological Discovery in the Birmingham District is intimately bound up with the history of British Geology in general, and dates back to the time of Hutton and Playfair. Playfair, in his "Illustrations of the Huttonian Theory" (1802), noticed the Pebble Beds and pebbly drift of the Midlands, and referred both to the stratified Lickey Quartzite as their probable source of origin. William Smith, between 1780 and 1815, first distinguished the three prominent rock systems of the district—the Carboniferous, the New Red Sandstone, and the Jurassic (Lias and Oolite), and defined and mapped some of the larger divisions of the last named groups. Professor Buckland, in 1821, examined and described the Quartz rocks of the Lickeys, and noted the igneous rocks of Barnt Green. He observed the Transition (Silurian) rocks on the flanks of the hills, as well as the associated Carboniferous beds, paralleled the Lickey Quartzite with the Quartzite of the Wrekin and Caradoc, and concluded that the Lower Lickey Hills "existed as a group of Palæozoic Islands surrounded by the New Red sea." He even asserted that "the true place of this Lickey Quartz rock appears to be at the lower extremity of those deposits known as the Greywacke." These rocks of the Lickey, and also those of the Nuneaton district, were next described by the Rev. James Yates in 1829, and both were correctly paralleled by him with the Wrekin and Caradoc series of Central Shropshire. Murchison spent much time in the District between 1825 and 1835, and devoted an important part of his great work on the "Silurian System" to a description of the Midland rocks; his account of the Silurian strata of the Dudley and Malvern areas is classical. He gave a full account of the New Red of the Midland region, and carefully distinguished the Midland Permian strata, which Buckland

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had confounded with the *Old* Red Sandstone, as the lower half of the *New* Red Sandstone, and paralleled the group as a whole with the Rothliegende of Germany. The Permian "trappoid breccia," however, he believed to mark the outcrop of an igneous rock, and he claimed the Lickey Quartzite as being of Silurian age (Llandovery), believing it to graduate upwards into the Llandovery fossiliferous sandstone of Rubery. He suggested that the Lower Lickey Hills lay along an old volcanic fissure (marked by an igneous rock occurring at Kendal End, near Barnt Green) by which the Silurian beds had been changed into quartzite.

A second period in the history of geological research in the Birmingham District is marked by the work of the National Geological Survey.

The mapping of the District by the officers of the Survey was carried out between 1840 and 1860, mainly by Sir A. Ramsay, Prof. Jukes, Prof. Hull, Mr. Howell, Prof. Phillips, Sir A. H. R. Selwyn, and Mr. Aveline. Prof. Phillips mapped the district of the Malvern and Abberley Hills, and described the rocks in the second volume of the Memoirs of the Geological Survey. Jukes (who was a native of Harborne, near Birmingham), mapped the South Staffordshire Coalfield, and his memoir on "The Geology of the South Staffordshire Coalfield," is a model of what such a work should be; but even the second edition has long been out of print. Hull mapped the Leicestershire Coalfield, and (mainly within the limits of the Birmingham District) fixed the boundary between the Permian and Triassic systems, distinguished and named the accepted divisions of the Midland Permian, Bunter and Keuper formations, and ascertained their sequence in the district. His Memoir (1869), "On the Triassic and Permian Rocks" of the Midland Counties of England, is still the standard work upon the subject. Howell mapped the East Warwickshire Coalfield and the surrounding country, embodying his results in his well-known "Geology of the Warwickshire Coalfield." Ramsay gave a general superintendence to the whole work, and studied personally the more difficult points and problems. The final result of the work of the Surveyors was to place before the public a complete series of geological maps covering the whole area of the Birmingham district, coloured so as to represent not only the various geological systems recognised, but also their main subdivisions. These maps were upon the scale of one inch to the mile—the only scale then published—and when we have regard to the smallness of this scale, and the minute character of the geological work, the general accuracy of the geological lines inserted upon them is beyond all praise. They were illustrated by many coloured longitudinal sections across the more typical parts of the country (upon a scale of six inches to the mile), and by vertical sections

(upon a scale of forty feet to the inch) of the strata pierced in the shafts of the chief collieries of the Midlands.

During the progress of the Survey many fresh discoveries were made and many novel views brought forward. The Surveyors proved beyond doubt that the "trappoid breccia" of the Permian was not the disintegrated surface of an igneous mass, but formed a constituent stratum of the Permian system. To explain the position and probable mode of formation of this breccia, Ramsay wrote his famous paper upon the subject, in which he advanced the theory of its glacial origin, and suggested its derivation from the distant Longmynd, Caradoc and Wrekin areas of Shropshire. Jukes, on the other hand, was led by his field work to the opposite opinion, namely, that the breccia was probably derived from ancient rocks in the immediate neighbourhood, which were exposed to denudation in the Midland areas during Permian time, but were afterwards buried from sight by later deposits. Again, while Buckland had published his opinion that the Lower Lickey Hills had existed as islands in the New Red Sandstone sea, and were enveloped unconformably in the surrounding mass of New Red sediments, Ramsay held that the field work showed that they were bounded by faults on both sides, along which they must have been relatively elevated since New Red times. Further, as no stratigraphical break was discoverable at Nuneaton between the Hartshill Quartzite with its associated rocks and the overlying Coal Measures, Ramsay felt himself unable to accept the views of his predecessors that they were of the age of the Wrekin and Lickey Quartzites, and they were consequently coloured by him on the Survey Maps as Millstone Grit and Lower Coal Measures.

The period (1856-1881) which followed the publication of the Survey Maps and Memoirs, was marked by the brilliant petrographical researches of the late Mr. Samuel Allport (a native of the district), and by the discoveries and conclusions of those geologists who were busied in developing the Archæan rocks which existed either within the boundaries of the district or in areas more or less related. Allport's description of the *Dolerites* of the South Staffordshire Coalfield, the *Diorites* of the Nuneaton district, and of the *Rhyolitic* lavas and agglomerates of the Wrekin and Wrockwardine areas, are classic in the history of British petrology. Dr. Holl's account of the so-called metamorphic gneissose and schistose rocks of the Malvern Hills (published in 1865), in which the original suggestion was made that these rocks were probably of Laurentian or Archæan age, was the pioneer of that host of geological papers dealing with the Archæan and pre-Cambrian rocks of Britain which dominated our geological literature for the next twenty years. In 1876 Dr. Hicks distinguished and named the Pebidian rocks below the Cambrian of St. David's. In 1877-8 Professor Bonney and the Rev. E. Hill published the sequence of the Charnwood Forest rocks, and in 1878 threw out

the suggestion that they might be of Peibidian age. During these years, also, Dr. Callaway published accounts of his original and far-reaching researches in Central Shropshire. He first announced (1877) his discovery of a typical Tremadoc fauna in the Shineton Shales, and showed (1878) that the stratigraphical evidences led to the conclusion that the Wrekin Quartzite (in place of being of Bala age, as previously supposed) was either of Cambrian age, or more probably, Archæan. Discovering that the Wrekin lavas and pyroclastic rocks (afterwards named by him *Uriconian*) underlay this Quartzite unconformably, he drew (1879) the conclusion that they must be of pre-Cambrian (or Archæan) age, a conclusion which is now almost universally accepted. In 1880 he showed that rocks similar to those of the Wrekin occurred in the Malvern range near Herefordshire Beacon, overlying the gneissose rocks unconformably. For this underlying gneissose series he had already suggested the title of *Malvernian*; and a few years later he employed the title of *Longmyndian*, as a designation for the unaltered pre-Cambrian rocks of the Longmynd.

The final period, namely, from the commencement of 1882 down to the present time, has been marked mainly by discoveries in the stratigraphy of the various geological formations of the Birmingham District and by researches among the Midland Glacial deposits. We may first treat of the Cambrian and pre-Cambrian rocks. Early in 1882 the unconformity between the Llandovery Sandstone of Rubery and the Lickey Quartzite was discovered in the field independently by Mr. F. T. S. Houghton and by Professor Lapworth. During the same year Lapworth detected the bedded pyroclastic basement rocks of Barnt Green in the area in which Murchison had recognised intrusive igneous rocks, but which had been mapped as an outcrop of the Permian breccia. A short time afterwards Lapworth and Mr. W. J. Harrison ascertained the bedded nature of the supposed intrusive igneous rocks of Caldecote near Nuneaton. Lapworth next discovered the Cambrian fossils of the Stockingford Shales, and worked out the sequence of the beds; and Harrison discovered the Cambrian inlier of Dost Hill. These results led to a revision of the Nuneaton area by the Geological Survey. In 1885 Mr. A. Strahan re-mapped the area, and proved, for the first time, the unconformity between the Cambrian and Carboniferous. The officers of the Survey made a collection of the Cambrian fossils of the district, and in the next year (1886) a revised edition of Sheet No. 63 S.W. was issued to the public, in which the rocks were coloured as *Lower Silurian* (Cambrian), and assigned to the general horizon of the Lingula Flags. The results of the local stratigraphical work up to this date will be found summarised in the chapter (much of which is incorporated in the present paper) on the Geology of the Birmingham District in the "Handbook of Birmingham," prepared for the members of the British Association

(in 1886). The subsequent discovery by Lapworth of *Olenellus* and *Paradoxides* in the Comley rocks of Shropshire, led him to assign the Wrekin Quartzite and Comley Limestone to the Lower Cambrian. This was soon followed by the detection of *Olenellus* in the north-west of Scotland by the officers of the Survey in 1891, led to a renewed search for fossils in the Upper Quartzites of Nuneaton. Casts of fossils were first detected in the bands at the top of the quartzite by Dr. T. Stacey Wilson in 1895; and during the same year the more deeply-seated *Hyolithus* beds of Camp Hill were discovered by Lapworth, and theoretically assigned by him to the Lower Cambrian. In 1895-6 Professor Watts, then of the Geological Survey, revised the geology of the Basement Rocks of Charnwood Forest, and in the Annual Report of the Survey for 1896 they are definitely assigned to the pre-Cambrian. In 1897 Mr. Walcot Gibson completed his revision of the Lickey and Barnt Green areas, and in the new edition of Sheet No. 54 N.W. the Barnt Green Rocks are recognised, and the Lickey Quartzite is coloured as Cambrian; while Permian and Bunter beds are shown as existing to the north-east of the Lickey range in ground formerly mapped as Keuper.

Coming next to the post-Cambrian formations, we find that the fossils detected by Mr. H. Johnson and Mr. F. G. Meachem in the supposed Permian rocks pierced in the shafts of Sandwell and Hamstead, were studied by Mr. Kidston, and the rocks were assigned by him to the Upper Carboniferous. The strata in the neighbourhood of the Forest of Wyre were subsequently investigated by Mr. T. C. Cantrill, who discovered Silurian rocks in an anticline at Trimley; and a *Spirorbis*-limestone band, and several distinct coal seams in the so-called Permian rocks of the Enville country. Mr. Wickham King has successfully devoted himself to the investigation of the composition, mode of accumulation, and source of origin, of the Permian Breccia occurring in the many exposures within the limits of the Birmingham District, the Calcareous Conglomerates in the underlying beds, and the remarkable mixed conglomerates of the Upper Coal Measures; while Mr. R. D. Oldham has published a most interesting comparison of the Permian Boulder beds of the district with the corresponding beds of India, Africa, and Australia. Professor Bonney has investigated the Pebble Beds of the northern part of the district, and Mr. T. Harrison those of the south, and have published their views as to their probable sources and their special mode of origin.

The petrology of the rocks of the Permian breccia has been partly worked out by Mr. W. Boulton and by Mr. Harrison, jun., and that of the Pebble Beds by Professor Bonney and by Mr. Waller. Mr. Waller has also published a paper on the intrusive igneous rocks of the Caldecote series.

Side by side with this stratigraphical and petrological work,

much has also been done during this period in the study of the Glacial deposits of the District. The original investigations and suggestions of Mackintosh and his predecessors, with regard to the local distribution and probable sources of the Midland erratics have been greatly extended by the researches and papers of the late Dr. Crosskey and of Mr. W. Jerome Harrison. Mr. F. Martin has mapped out the main distribution of the Midland erratics, the late Professor Carvill Lewis discussed the arrangement of the Arenig boulders, and Mr. H. G. Mantle has recently investigated the local distribution and probable sources of the erratics in the neighbourhood of Lichfield.

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LONG EXCURSION TO THE BIRMINGHAM DISTRICT.

THURSDAY, July 28th, to WEDNESDAY, August 3rd, 1898.

Directors: PROF. C. LAPWORTH, LL.D., F.R.S., W. JEROME HARRISON, F.G.S., W. WICKHAM KING, F.G.S., T. STACEY WILSON, M.D., M.R.C.P., AND PROF. W. W. WATTS, M.A., SEC. G. S.

(PLATE XIII.)

Excursion Secretary: F. MEESON, F.G.S.

(Report by W. W. WATTS; revised by the other DIRECTORS.)

THE greater part of the area known as the Birmingham District is occupied by the Trias, a deposit which is a mile in depth where all its members are present in full thickness. Submerged more or less completely under the Trias, several ancient ranges of Palæozoic Rocks, the strikes of which radiate as it were from the Southern end of the Pennine Range, form a broken chain which crosses the district about its centre in a direction extending roughly from S.W. to N.E. Certain portions of these ridges are still high enough to peer out from beneath the Triassic covering, so that it is possible to study in them all the Palæozoic systems but two within a short distance of the city. The Ordovician Rocks have not hitherto been found *in situ*, although fragments of them are known to occur among the Bunter pebbles; the Old Red Sandstone has, up to the present, only been met with in two sinkings in the South Staffordshire Coalfield.

The series of excursions was so planned that, on the whole, the oldest rocks were studied first, and the members of the Association were introduced to newer and newer rocks in order. The incidence of Bank Holiday interfered slightly with this sequence, while it also rendered it practically impossible to devote any time to Carboniferous Rocks except in distant views, for which the weather and atmosphere were exceptionally favourable.

After journeying to Birmingham on Thursday, July 28th, and taking up their quarters at the Grand Hotel, the party travelled by the first convenient train to Nuneaton, and began their week's work there. Roughly speaking, it may be said that the Nuneaton district consists of a strip of pre-Cambrian and Cambrian Rocks, striking N.W. and S.E., sandwiched between Triassic Marls to the N.E. and Coal Measures to the S.W. The Trias is separated from the pre-Cambrian (Caldecote) Rocks by a fault coursing N.W. and S.E. The pre-Cambrian strip is followed to the S.W., unconformably, by Cambrian (Harts-hill) Quartzite, Limestone (the Hyolite Limestone), and Shales (the Stockingford Shales). Farther still to the S.W. the basement beds of the Coal Measures follow with a marked unconformity.

NOVEMBER, 1898.]

On leaving the railway station the party at once made their way to a large quarry near, in which was seen the first exposure of Hartshill Quartzite; this is well jointed and pierced by a diorite dyke 40 ft. or 50 ft. thick. But the chief interest of the quarry is the unconformable junction with the Trias which is shown in its upper part. A breccia, made up of angular fragments of quartzite, here forms the base of the Waterstones, and it is followed by layers of well-bedded, red and brown sandstone. The junction is of importance, as it seems to show that the eastern boundary fault of the Palæozoic area is not a very great displacement.

The Lower Beds of the Quartzite (Park Hill Quartzite), and their numerous sills and dykes of diorite, were studied in a line of old quarries; but the hunt for the "needle rock"—a diorite with small hornblende prisms visible in it—was not as successful as had been hoped, owing chiefly to the unfavourable weather. Nor was a passing glance at the shales, interbedded with the quartzite, rewarded with the discovery of any pre-*Olenellus* fossils.

After halting under a shed for a sharp thunderstorm to blow over, the geologists next visited Mr. Boon's quarry, a locality now classic from the fact that the basement layers of the Quartzite which are exposed here, are full of fragments, large and small derived from the denudation of the underlying Archæan (Caldecote) Rocks. This exposure was one of the first which originally gave the required evidence as to the relative ages of the Caldecote volcanic series (pre-Cambrian) and the Quartzite (Cambrian). A recent excavation in this quarry (kindly brought under the notice of the Directors by Mr. Boon) has revealed an excellent example of beds near the base of the Quartzite, entirely made up of blocks and boulders, varying from 1 in. to 3 ft. in length. The boulders consist of different members of the underlying Archæan series and other ancient rocks. Thus specimens of basic and intermediate ash, quartz-felspar ash, quartz-porphry, and porphyritic basalt, all of types recognised amongst the Caldecote group, with hälleflintas, fine green ashes, and quartzites resembling the rocks of the Charnian series (of Charnwood Forest), and pieces of plutonic rock from an unknown source, were collected by the members.

The next exposure visited was the well-known "Blue Hole" near Caldecote Hill House, in which the Archæan Rocks were for the first time seen *in situ*. Owing to the previous rainfall the rocks were not easy of access, but, when reached, they were found to be much improved by their recent washing. At this place a rock, which appears to be a quartz-felspar tuff, such as might have been blown out of a volcano discharging quartz-felsite lava, has been invaded and overlain by a porphyritic basalt, veins and strings of which were to be seen on the face of the exposure piercing their way into the joints and cracks of the quartz-felspar

rock, and even running in the finest threads amongst its disintegrated fragments. Specimens of the "mixture rock," with varying proportions of the acid and basic ingredients were carried away by the members for microscopical investigation.

The day's work was closed by a visit to the old tunnel near Caldecote Hill House. The remarkably fine, dust-like, laminated tuffs of Archæan age, part of the Caldecote series, are, or rather were, still to be found here; whether future visitors will find any or no is quite another question. Slightly coarser tuffs, not so markedly laminated, are, however, to be found here in plenty.

On *Friday, July 29th*, a few more quarries in the Lower and Middle Divisions of the Quartzite were visited. Amongst them were two of very considerable interest. The first, belonging to the Messrs. Trye, revealed what was left of the dyke shown on Plate X, Fig. 2. Here the diorite was plainly seen to cross the bedding of the Quartzite in the direction of its dip, although corresponding with it in strike. The quarrying which has taken place since the photograph was taken has revealed the fact that the dyke thins down from 3 ft. to 1 ft. in breadth, while a new sill, conforming to the bedding, has made its appearance.

A call for petrologists to make a detour in order to see an example of the nodular diorites—called "anchorites" by Professor Lapworth—revealed the fact that two-thirds of the party claimed this title. The spot was soon found, at the entrance to Messrs. Trye's quarry, where a thin sheet of diorite, intrusive into the lower layers of the quartzite, has segregated on cooling into basic clots and acid veins. A big block was soon extracted and dismembered, its fragments being carried off to decorate several museums ranging from Oxford to Exeter.

The entrance-cutting to Mr. Abel's quarry was next studied carefully, as it yields perhaps the most interesting to a geologist of all the numerous sections in the district; for this is the only place where the actual junction of Cambrian and pre-Cambrian rocks can be seen and worked out in detail. The pre-Cambrian, Caldecote rocks consist chiefly of quartz-felspar ash like that seen in the "Blue Hole," and they are similarly pierced and invaded by porphyritic basalt, which, in this case, traverses them as a vertical dyke. These rocks are covered by Quartzite, whose lower layers, as in Mr. Boon's and Mr. Trye's quarries, are made up of Archæan *débris*. In spite of this fact, and that the junction is somewhat irregular, any unconformity of the two sets of rocks is masked by their correspondence in dip and strike, and by the anticline over which both rocks are folded. The field evidence for unconformity rests on the boulder-beds and the pebbly and gritty layers in the Quartzite already mentioned, and also on the weathered condition of the quartz-felspar rock near its junction with the Quartzite. While this rock is sound and fresh at the bottom of the cutting, and far below the Quartzite junction, its

contact layers are weathered to a depth of 8 ft. or 10 ft., and split up into spheroids of all sizes, one being 6 ft. or 7 ft. across. Other evidence will be found on pages 393 and 394.

From this point the party travelled to the abandoned cutting near Camp Hill Grange, the site of the Hyolite Limestone, with its associated beds, now classed as the Highest or Camp Hill Division of the Quartzite. The succession was soon made out: Sandy, glauconitic, and phosphatic layers below; then the red limestone; then more layers of quartzite, calcareous bands, and sandstone; and, finally, the lowest purple beds of the Stockingford Shales, pierced and altered by several diorite sills. Great masses of the red Hyolite Limestone were soon extracted, and specimens of *Coleoloides*, *Kutorgina*, *Orthotheca*, and several species of *Hyolithus* were carried off. Professor Lapworth, who had taken several opportunities on this and the previous day to explain the geology as the ground was traversed, here pointed out that the Hyolite Limestone, although it had yielded no trilobites, probably occupied the place of the *Olenellus* rocks of Shropshire, the Highlands and elsewhere, for the species of *Hyolithus* and other fossils in it compared more closely with those of the *Olenellus* zone of Norway and America than with any others. This identification fitted in with other facts; it placed the Harts-hill Quartzites in line with those of the Wrekin and of Erribol as the base of the Cambrian System, while it correlated the Camp Hill Quartzite with the Comley Sandstone of Shropshire, and the "Fucoid Beds" of the Highlands.

Joining the carriages, the party drove to Chapel End, and after lunch they pressed on to the new railway cutting now being made by Messrs. Trye, north of the village. This cutting exposes a fine section of black Stockingford Shales (Oldbury Shales), bent back and folded by the soil-creep down the hill-slope. In addition to this it shows the unconformable junction of the Coal Measures. The lowest Carboniferous rock is a conglomerate in which pebbles of vein quartz are very common, but fragments of quartzite and diorite are also of frequent occurrence. Yellow sandstones succeed, and the cutting plainly shows that the diorite dykes, like the shales, were cut off by denudation before the Carboniferous rocks were deposited.

Partly walking and partly driving, the members went on to a large exposure of diorite, intrusive into the shales at Raspberry Knob, near Purley Park, where very fresh examples of diorite, containing large crystals of hornblende, and a small amount of olivine, were collected. The lane near Purley Park, which was next visited, shows a fine exposure of the Lowest Division of the Stockingford Shales, the purple or *Purley Shales* named after this locality, the probable equivalent of the Menevian Rocks of North and South Wales. Several fossils, including *Obolella*, *Hyolithus*, and *Agnostus* were obtained, and for the first time the head of a

Conocoryphe was found by Mr. Ridley, and generously presented by him to the Mason College Museum.

A very beautiful drive through Merevale Park and past Merevale Abbey, by the kind permission of Lady Dugdale, brought the party to an old quarry, in which, with Professor Lapworth's assistance, a thin seam of grey shale was unearthed and yielded sufficient specimens of *Dictyonema* to provide most of the members with one. These shales, the *Merevale Shales*, form the highest division of the Stockingford Group, and seem to find their parallel in the Upper Dolgelly Division of the Lingula Flags of North Wales.

Tea at Atherstone concluded a day which rocks, fossils, and weather had combined to make delightful, and the party were charmed with the beauty of the country traversed, the wealth of exposures, and the generosity with which the owners of quarries and of property had allowed them to visit and collect over the whole country-side with the utmost freedom.

Saturday, July 30th, was not an ideal day for travelling, and it was only after many delays that the members of the Association alighted at Barnt Green and were able to resume their normal shape and size, after the compression necessary to put sixty people into a train every carriage and van of which was already over-full, and which still stopped, hungry for more passengers, at every station *en route*.

After hearing a brief account of the district from Professor Lapworth, the party invaded the grounds of Barnt Green House, the owner of which, Mr. Everett, had generously given them permission to examine the unique section of Archæan Rocks exposed along the brook. Here specimens of tuff, banded and otherwise, and of an intrusive basic rock, were collected, and the general correspondence of the rocks to those of Caldecote was pointed out, and it was suggested that we have here a fragment of the Southern ranges, now buried under the Trias, from which the Permian breccia material came down. On traversing a field on the way to Kendal End, the hedgerows were found to be full of angular blocks of similar rocks, which may be the result of present-day weathering, or may be part of a scree formed in Permian times. Perched on the top of this hill an outlier of Silurian (? Woolhope) Limestone, now entirely quarried away, originally rested on the top of the Archæan Rocks with apparent unconformity. The well-known dyke of diorite intrusive into the Archæan Rocks, and the black shale which Mr. Gibson discovered to the west of this spot, were visited, and also a corresponding diorite dyke on the east side of the hill. Crossing the transverse fault which separates the Archæan and Silurian Rocks of Kendal End from the Quartzite that makes up the core of Bilberry Hill, the party next halted in Bilberry Hill Quarry (See Plate XI, Fig. 1), and the remarkable

overfold in it was studied. The interpretation that the overfold was part of an inverted syncline was accepted, and the portion seen to the left in the figure seemed to have been let down by a fault. The quartzite of this exposure is in appearance like the lower divisions of the Nuneaton (Cambrian) Quartzite, with which it is now correlated, as its unconformable infraposition below Llandovery Sandstone renders it unlikely that it should be of any other age. Many seams, more or less conglomeratic, found in the quartzite of this quarry, like the basement layers at Nuneaton, are made up of *débris* derived from the (Barnt Green) Archæan Series below. These strengthen the view that the Barnt Green Series is Archæan; satisfactory proof by superposition is wanting.

An ascent of Bilberry Hill was next made, but the heat-haze interfered with a distant view. The salient features in the geology of the hills were pointed out by Prof. Lapworth, and then, on descending the other side, the Bunter Pebble Beds overlapping the western side of the hills were seen in a small quarry. The quarry in the Quartzite near the keeper's lodge furnished specimens of typical quartzite, often with well-rounded grains and well bedded, while grains of glauconite were common in many specimens.

After lunch the party pushed on towards the Beacon Hill, passing off the Quartzite over vertical layers of sandstone, and over the place of the Permian Marls on to the Permian Breccia, the latter standing up as a line of hills on account of the porosity of the rock which hinders the gathering of streams and the denudation resulting from them. The similarity of the breccia to the unconsolidated scree-material of the Archæan slopes already seen was remarked.

At the village of Rubery, Llandovery Sandstone was seen resting unconformably on the Lickey Quartzite. The junction



FIG. 1.—TRACING FROM PLATE XIII, FIG. 2, TO SHOW THE EXACT RELATIONSHIP OF THE LLANDOVERY SANDSTONE (STIPPLED) TO THE CAMBRIAN QUARTZITE (NOT STIPPLED). A FISSURE IN THE QUARTZITE, FILLED WITH SANDSTONE WILL BE SEEN ALONG THE LINE *f. f.*

a.

b.



FIG. 1.—VIEW (LOOKING SOUTH-WEST) FROM THE HOUSE OF MR. MANDER, "THE MOUNT," TETTENHALL, WOLVERHAMPTON.

a. Titterstone Clee Hill. b. Brown Clee Hill.

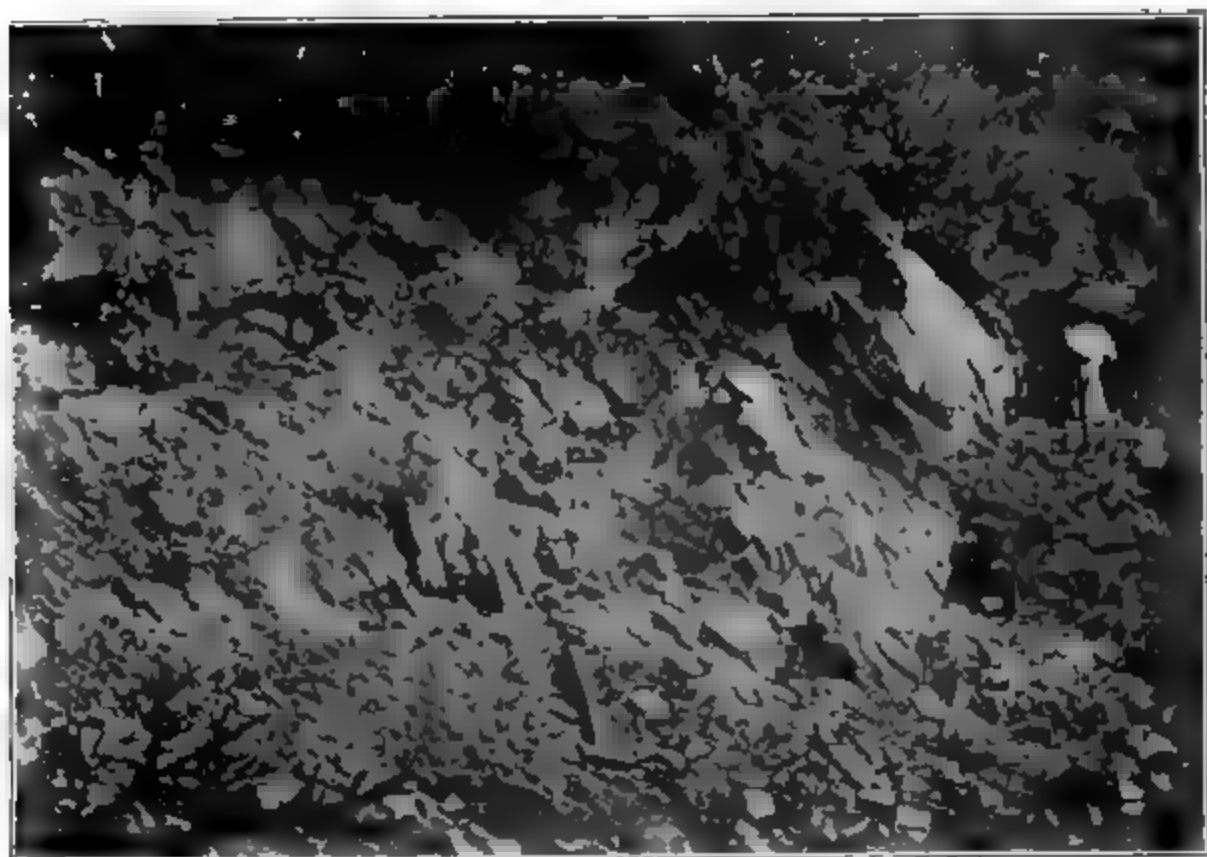
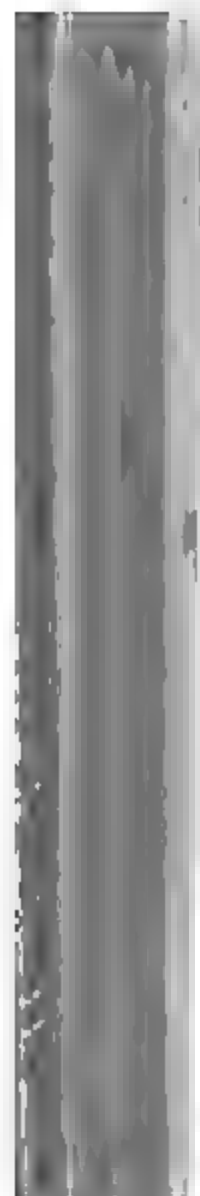


FIG. 2.—SECTION AT RUBERY TO SHOW LLANDOVERY SANDSTONE RESTING UNCONFORMABLY ON CAMBRIAN QUARTZITE. THE LLANDOVERY ROCK FILLS UP FISSURES IN THE QUARTZITE. (See Fig. 1 for Key).

(From photographs by Professor H. E. Armstrong).



was photographed when it had been cleared, and junction-specimens were collected, some of them with fossiliferous sandstone filtering into the cracks of the quartzite. A photograph (Plate XIII, Fig. 2) of this junction was taken by Prof. H. E. Armstrong, and the annexed tracing (Fig. 1) will serve as a key to it. It was the discovery of this section which first showed that the Lickey Quartzite was not of Silurian (Llandovery) age as had been previously supposed. In the grounds of the Asylum, to which the members were next conducted, the Llandovery Sandstone was seen to be succeeded by fossiliferous Woolhope Limestone, and that by Wenlock Shales.

After tea the party made their way to Rubery Station, and at Holly Hill they saw the most northerly exposure of the Quartzite in the district, a mass now being quarried away to furnish material for making a new reservoir on Frankley Beeches. A striking fault was seen to pass through this point and to throw down Carboniferous sandstone into contact with the Quartzite.

Some spare hours were taken up with a pleasant stroll from Aldridge past Barr to Barr Beacon and Sutton Park. A considerable area of Silurian rock ranges from Walsall and Rushall to Hay Head, in the parish of Barr, and in this the three Silurian Limestones are displayed, the Wenlock Limestone, as usual, being double. At Hay Head the lowest limestone, the Woolhope or Barr Limestone, used to be quarried for smelting purposes but the quarries are now abandoned, great grooves marking the former site of the outcrop. From this locality most of the characteristic fossils of the Woolhope Limestone have been obtained, including *Illænus barriensis*, named after the locality. The Association was fortunate in carrying away, amongst many other fossils, one almost whole specimen of this rare fossil and several imperfect but recognisable fragments. After a good hunt in the abandoned quarries the party rested on an old spoil bank, and the fortunate discovery by Mr. Garwood that small brachiopods were to be found there set everybody "beach-combing," with the result that each one carried away a handful of the tiny brachiopods so characteristic of the Wenlock Shale, including such of the rarer forms as *Streptis grayi*, *Retzia*, and *Waldheimia* (? *mawi*), as well as dozens of such forms as *Atrypa marginalis* and its varieties, *Cyrtia exporrecta*, *Orthis elegantula*, *O. elegantulina*, *O. hybrida*, and *O. viloba*.

A welcome halt at the foot of the hill near some old coal-workings was followed by a climb up the fine escarpment of Bunter Pebble Beds, known as Barr Beacon, from the summit of which there was a superb view both east and west as the Black Country smoke had settled down for its Bank Holiday rest. Three-fourths of the Coalfield were plainly visible, its south-west part being cut off by the line of hills which follows the Dudley anticline, Rowley, Dudley Castle, the Wren's Nest, and Sedgley

Beacon. Beyond the Coalfield there rose to the north the Wrekin, then the Brown Clee Hills and the Titterstone Clee, the last two being little coalfields capped by a sheet of dolerite like that of Rowley. (See Plate XIII, Fig. 1, taken from a photograph by Prof. H. E. Armstrong.) The Permian ranges framing the Black Country were clearly seen, culminating in the Clent and Lickey Hills to the south. To the north and east the view ranged over the woods and wastes of the Bunter Pebble Beds, which extend from Cannock Chase to Streetly and Sutton Park.

Descending the hill the party next entered Sutton Park, where Mr. Harrison pointed out the remains of the old Roman road of Icknield Street, and, after a delightful walk through the Park to Blackroot Pool, they studied a capital exposure of Bunter Pebble Beds. The pebbles and matrix are traversed by joints, and where one pebble comes into contact with another the softer one is generally indented, while the smaller one is often crushed by earth movement so that it crumbles to pieces on being extracted. The pebbles are mainly of varieties of quartzite which have not yet been found locally *in situ*, but, in the course of the day pebbles of Lickey Quartzite, and of Llandovery Rock sometime fossiliferous, were collected. A few pebbles of fossiliferous *Grè Armorica* were also obtained.

An early start was made on Monday, August 1st, for Wolverhampton, and a visit was made, under Mr. Jerom Harrison's direction, to the West Park, in which the Corporation have preserved a couple of large boulders—one from Criffel, and the other from Arenig or the Lake District (Fig. 13, p. 406). The party next drove to Tettenhall, where they were hospitably entertained by Mr. C. T. Mander at breakfast, after studying a fine collection of boulders amassed by that gentleman's father. The majority of the boulders had come from Lakeland and South Scotland, but there was at least one "Welshman" in the collection. The roof of the house commanded an excellent view over the country to the west, and there was no difficulty in recognising the features previously seen from Barr Beacon, while, in addition, the Longmynd, with Corndon beyond and the Stretton Hills in front of it, and the Abberley and Malvern ranges to the south, were well seen. (See Plate XIII, Fig. 1). After taking leave of their kind host the party drove on to Trescott, Trysull, and Seisdon, a country strewn with millions of boulders, amongst which the following were recognised: Granites from Eskdale, Skiddaw, and the Galloway region; granophyre from Buttermere; felsite from St. John's Vale (?); felspathic dykes from S. Scotland and Lakeland; tuffs and andesites from Lakeland and Arenig; hornfels, possibly from the Shap district; and a striking augite-andesite, most probably from Falcon Crag, in Borrowdale, though it had affinities with a

rock of the same age found near Shelve, in Shropshire. After traversing Abbott's Castle Hill and Highgate Common, the party halted for a while at Enville, one of Ramsay's classic localities, and then skirted Enville Park to see the Permian Calcareous Conglomerate, a bed which has recently been made the subject of a paper by Mr. W. Wickham King.

Before reaching Compton quarry a very beautiful view of Kinver Edge and the surrounding landscape tempted Professor Lapworth to develop his idea of the rejuvenescence of the Severn valley, owing to the diversion into it of the drainage of the Upper Dee in glacial times. The deepening of the main Severn Valley from Coalbrookdale to Stourport, due to the increased erosion brought about by the great increase in [the water supply, had permitted the tributary streams entering this part of main valley to cut deep gorges for themselves in the lower parts of their courses. The slope of the stream-beds here became more steeply inclined, and the rate of transportation increased, resulting in a more rapid and more differential local denudation. The result is seen in the bold and picturesque scenery of the lower halves of their basins, in marked contrast with the more rounded and featureless country farther back, which remains as yet unaffected. The jointing of the Calcareous Conglomerate was studied and photographed, and Mr. King pointed out the chief kinds of Silurian and Carboniferous Limestone which made up most of the pebbles. The climb up Kinver Edge led past the dwellings of Holy Austin Rock which have been dug out of a hard bed in the Lower Mottled Sandstone. The summit of the ridge gave a fine view, including the Abberley Hills and the Malverns rising out of the Triassic plain. The drive back to Stourbridge Junction was past a couple of very fine exposures of Pebble Beds, that at Wollaston Ridge yielding several examples of fossiliferous pebbles.

The Director for *Tuesday, August 2nd*, was Mr. W. Wickham King, who met the Association at Stourbridge, and went on with them to Kidderminster. The object of this excursion was to study some of the complicated relationships of the so-called Permian and Triassic sediments to the underlying Palæozoic rocks. Mr. Wickham King has kindly furnished the following brief note on his views, as expressed by himself and Professor Lapworth to the Association on the ground :

"The fact of an inversion of the Silurian and Old Red Strata on the western flanks of the Abberley range was originally pointed out by Phillips. According to the views and discoveries of the Director, the structure of the district is in its way quite Alpine. Not only are there inversions, but there are actual overthrusts, the Wenlock and Aymestry Limestones and the Lower Ludlow Beds being repeatedly forced over on to the Old Red Sandstone and Upper Ludlow Rocks. The strike of the

axes of the main folding of the country is first north and south in continuation of the main axes of the Malvern ridge (Malvernian folding), but at Abberley Hill it swings round almost at right angles to this direction, the axes now striking from west to east (Hercynian or Mercian folding). The great complication and overthrusting is at the 'elbow.' Upon these two major axes or directions of folding are superposed minor folds or 'ripples,' namely, on the Hercynian portion folds with axes running from N.W. to S.E. (Charnian or Woolhope folding), and on the Malvernian portion ripples with N.E. to S.W. axes (Scandinavian).

"The complicated Abberley elbow forms a fan-fold with overthrusts upon its outside edges and a sag in the middle. In this sag lies the so-called 'Permian Breccia' of the locality. The mountain-making movement must have commenced as early as Carboniferous times, for the Coal Measures rest unconformably upon the Downton Sandstone, and it must have continued far into Triassic time. At the time when the "Permian Breccia" of the locality was laid down the movement was not finally closed, for many of the fragments in it are slickensided. This complicated little district gives probably a rough idea of the rest of the Mercian Highlands, the ruins of which, with the exception of the Malvern, the Lickeys, etc., now lie buried deep beneath the Triassic mantle. The so-called "Permian Breccias" of the Severn basin, so intimately connected with these Highlands, are of several ages, ranging in time from the Upper Carboniferous to the Keuper."

On arriving at the Hundred House the party speedily made their way to Walsgrove quarry, where a little scrambling took many of them up to the point at which the Downton Sandstone and Upper Ludlow Beds. are inverted and thrust over the Aymestry Limestone and the associated nodular beds. Proceeding through Abberley Park, which the owner, Mr. Jones, had kindly allowed the party to cross, abundant fossils were obtained from exposures in the Wenlock Limestone, the Aymestry Limestone, and the Upper and Lower Ludlow Beds. The offer of a reward for graptolites at one spot stimulated research to such an extent that several examples were unearthed, proving for the first time that the beds there were of Lower Ludlow age, inverted and probably thrust on to the top of the Upper Ludlow Beds, seen in a quarry just below, or on to the Downton Sandstone. From a new excavation near here one of the members was rewarded by the find of about a dozen heads of *Phacops*, showing the faceted eyes, and other members also found *P. longicaudatus*.

The route up Abberley Hill led past a grand exposure of "Permian Breccia," resting on the truncated edges of the Silurian, from which were collected many examples of various tuffs

and ashes of Archæan type, as well as sedimentary rocks which could be matched with local rocks found *in situ* in the vicinity. A brisk discussion between Professor Blake, Mr. King, and Professor Lapworth elicited the contrast between the old views that the breccia fragments had been borne by glaciers from Wales, and the new views that they were of local origin, and derived from the cores of the Malvern ranges and their continuation near Abberley. The theory that steep mountain ranges existed here in early Permian times, with overfolding and overthrusting like those of Alpine regions, was startling; and the view that the Permian breccia was probably the scree of overthrust Archæan masses once overlying the Silurian here, but now wholly vanished, seemed to many more like a fairy tale than sober geological inference. The top of Abberley Hill gave a fine view towards the Malverns, Radnor, Shropshire, and Wales; but the most curious feature was perhaps the horse-shoe shape of the hill itself, resulting from the superposition of a north-east ripple on the dominant N. and S. waves of the Malvern Range.

In the evening a large party assembled at the Grand Hotel, and the customary votes of thanks to the Directors and those who had otherwise contributed to the success of the excursion were passed.

The excursion to Dudley on *Wednesday, August 3rd*, was of a kind quite unusual to the Association. By Mr. Cloughton's kindness, after the party had traversed the Castle Hill, and had the geology of the neighbourhood explained to them from the summit, they embarked in a limestone-barge and traversed the subterranean canal, excavated through the Silurian rocks which connect the Castle Hill and the Wren's Nest underneath the surface covering of Coal Measures. The weather broke somewhat on this day, but the showers were a matter of indifference to the members underground, and it was only after they reached the surface again that they were at all inconvenienced. Passing out of the canal, the party emerged into one of the groups of caverns formed by the excavation of the limestone for smelting and burning. This was brightly lighted up with hundreds of candles; and after Professor Lapworth had given an account of the geology of the hill as related to the industries of the surrounding districts, so far as they are dependent on the geology, the effect of the caverns was enhanced by the use of coloured lights. When the surface was reached, the geologists found a choice collection of Coal Measure plants obtained in the neighbourhood, and from this they were able to purchase such examples as they wished. Next, they collected specimens of brachiopods and corals from the Upper Ludlow Beds. Then, as the rain began again in a business-like fashion, the party walked from the Wren's Nest to the Priory, in answer to Mr. Cloughton's kind invitation. Here they were most hospitably entertained, and after they had expressed their

thanks to Mr. Claughton for his goodness to them throughout the entire day, the members of the Association made their way to the railway station. On the way Dr. Fraser distributed a series of duplicate fossils from his own fine collection, and the party closed its week's work with a vote of thanks to Mr. Meeson, whose work as Excursion Secretary had done so much to make the whole excursion a success.

EXCURSION TO HILLMORTON AND RUGBY.

SATURDAY, MAY 7TH, 1898.

Director: BEEBY THOMPSON, F.G.S., F.C.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by THE DIRECTOR.*)

OF the members who availed themselves of this excursion, those coming from London reached Northampton about 10.55 a.m., and others joined later on at Kilsby Station, Hillmorton, and Rugby respectively. From Kilsby and Crick Station a walk of about $1\frac{3}{4}$ miles brought the party to the first section to be visited, that near Hillmorton.

RED-BANK BRICK-WORKS.—These brick-works, visited by permission of the proprietor, Mr. Young, of Rugby, are situated to the east of Hillmorton village. It is a comparatively new section of Lower Lias that is worked, and no fossils have, so far, been found to indicate the zone. Attention was particularly called to the capping of coarse gravel, and to the inclination of the clay surface to the north at the northern boundary of the excavation.

HILLMORTON SAND-PITS.—A few yards only separates the last-named section from the very extensive sand-pits owned and worked by the London and North-Western Railway Company. These pits were visited by permission of Mr. W. H. Williams, of Watford. The following interesting characteristics were pointed out:

The excavation now exposed is about 50 feet vertical at the eastern end, and consists of sand and gravel, but the sand has been proved within the limits of the workings for another 130 feet; thus the sand and gravel are together about 180 feet thick. Water is found within 2 feet of the present working level, and some few years back the L. and N.-W. Ry. Co. bored 145 feet with the object of procuring a supply, but the quantity available was too small to be of service. Mr. R. Lowe, district superintendent, to whom we are indebted for some of these particulars, informed us that 15 feet below the present working level the sand becomes darker in colour.

The upper part of the exposed section consists of some 8 to
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10 feet of coarse gravel, which rests unconformably on the sand (or on an older gravel) as it does on the clay in the brick-yard. This very distinct separation of the two sets of deposits was best seen in a small sand pit nearer to the village of Hillmorton.

The sand rests against the northern face of a highly-inclined cliff of clay, for the boring proving such a great depth of sand is quite near to the Red-Bank brick-works; and Mr. Low said that once, when a slip of the sand from the face of the clay occurred, the clay was like a wall; moreover, the slope of the clay in the brick-yard, towards the sand-pits, was once measured, and found to be 25 degrees.*

Towards the eastern end of the excavation it is very noticeable how the material becomes coarser, until at the dead end the whole 50 feet would be better described as gravel than sand. Westward, along the face of the excavation, were seen long stretches of finely-bedded and of false-bedded sand, with here and there long thin bands of clay or of carbonaceous matter; less frequently lenticular patches of gravel occurred. The general dip is to the north-west, the angle, however, being small.

In explanation of the phenomena observed, the following propositions by the Director seemed to receive the assent of the members present: (a) that the sand (or gravel) occupies a former depression in the Lower Lias of the district; (b) that it is a true glacial deposit, in the sense that only the rapid melting of snow or ice could account for the long-continued and violent, though restricted, floods to which the deposit is due, as well as the varied character of the material; (c) that the torrents which brought the gravel, sand, and clay came from the north or north-east, and spent a large portion of their energy upon a barrier formed by the high ground north of Kilsby and extending through Hillmorton towards Dunchurch; (d) that the chief point of impact lay to the eastward of Hillmorton, in the direction in which the sand so rapidly passes into gravel; (e) that this line of impact was ultimately breached (or overtopped) by the torrents, in places, one being just about where there is now a depression bridged by the railway and cut through by the Oxford Canal,† and some of the gravel poured through this vent into the valley now occupied by the Rains Brook. This rounding of the Hillmorton ridge by the gravel is well seen to the east of Red-Bank brick-works, lower down the hill towards the canal wharf; (f) that one main flow of water, diminishing in velocity, was approximately that of the present Clifton Brook, the diminished

* This banking of drifts against the northern sides of hills has been noted before, see *Geology of the London Extension of the Manchester, Sheffield, and Lincolnshire Railway*, Pt. I, by C. Fox-Strangways, F.G.S., *Geol. Mag.*, Dec. IV, vol. iv, March, 1897, pp. 54 and 56.

† Another breach was probably between Crick and Kilsby, cutting through the south-eastern end of Kilsby tunnel, the material extending and expanding towards Welton and Daventry.

velocity being made apparent by the deposit of sandy, contorted Boulder Clay near to Rugby, visited later in the day.

THE CENTRAL BRICK-YARD, HILLMORTON.—This section was next visited, by permission of the proprietor, Mr. Rathbone, and a number of fossils obtained indicative of the "Armatus"-zone, the chief being *Ammonites planicosta*, *A. densinodus*, and *A. trivialis*.

After a rest of half-an-hour for luncheon at Hillmorton, the party proceeded to Mr. Satchell's brick-yard, about half-a-mile towards Rugby. The pit was too wet, owing to recent rains, to permit of an examination of the clay itself, but some fossils indicative of three zones of the Lower Lias, were obtained: *Ammonites densinodus* and *A. planicosta* from the "Armatus"-zone; *A. raricostatus* and *A. tardecrescens* from the "Raricostatus"-zone; and *A. bifer* and *A. oxynotus* from the "Oxynotus"-zone.

GREAT CENTRAL RAILWAY.—From Satchell's pit, a walk of a quarter-of-an-hour, brought the party to the Great Central Railway, where it intersects the Hillmorton and Dunchurch road. Only a very small portion of the slopes had not been grassed over, but this small portion permitted of an hour's collecting from the "Oxynotus"-zone, *Ammonites oxynotus*, *A. bifer*, *A. polymorphus*, *Gryphæa cymbium*, *Hippopodium ponderosum*, *Spiriferina walcotti*, and a few gasteropods, being the more noticeable fossils found.

Walking towards Rugby, Mr. A. W. Casson, the Resident Engineer for this portion of the line, pointed out a small temporary excavation, from which was obtained *Ammonites turneri*, *A. semicostatus*, etc., indicative of the "Turneri"- or "Semicostatus"-zone.

Contorted Boulder Clay.—A little nearer to Rugby there was an exposure of a considerable thickness of Boulder Clay. This is a brownish material which looks like and cuts like a clay when wet, but is far more like a soft grey sandstone when dry, easily crumbling in the fingers. It is a compound of sand and clay, the two materials being mixed up in the most erratic manner, giving a peculiar and pretty contorted appearance when half dry. As a rule this clay is free from any derived material—either rock or fossil—that can be identified, but here and there patches of gravel have been found in it containing a varied collection of pebbles and rolled fossils; at other places only masses of small fragments of chalk occur.

This Boulder Clay, like the sands of Hillmorton, rests on the northern side of an inclined face of Lower Lias Clay, except that a few feet of blue Boulder Clay with local Lower Lias fossils in abundance is interposed, this latter material being little more than the disturbed upper layers of the Lias beds on which it rests.

The contorted Boulder Clay is of considerable thickness, and everything seems to point to its being a contemporaneous and

continuous deposit with the Hillmorton Sands, being laid down in water the velocity of which had been considerably checked by a land barrier which it was unable to surmount. The small icebergs which would certainly accompany flood water derived from the rapid melting of ice was probably the cause of the contortions, by acting on the soft freshly-deposited mixture of mud and sand; and the stranding of such icebergs would account for the occurrence of isolated patches of gravel.

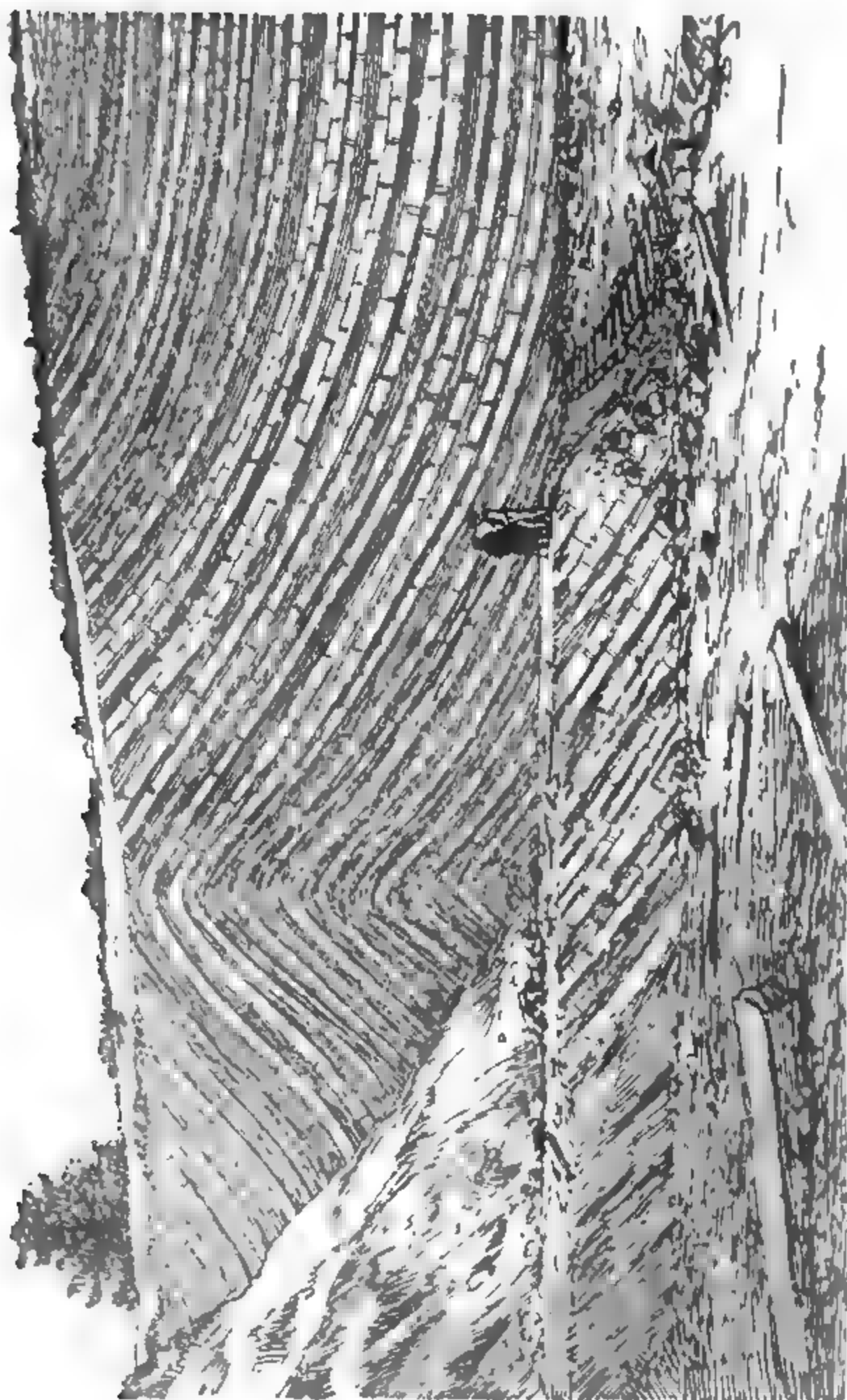
RUGBY PORTLAND CEMENT CO.'S WORKS.—A walk of about $1\frac{1}{2}$ miles through Rugby and New Bilton brought the members to the large quarry in the Lower Lias Limestones. Here they were met by Mr. Brooks, the manager, and Mr. Edyvean-Walker, the proprietor, who kindly invited them to partake of refreshments before going into the quarry.

The excavation is through the "Bucklandi" and "Angulatus" zones, and is considered to be the finest inland section of Lower Lias Limestones in the country. Attention was called to the beautiful banded appearance, which is supposed to have given to the whole formation the name of Lias, a corruption of the word layers. The entire absence of Boulder Clay or sand on the clay was pointed out, though the never-failing gravel capping was present. Passing through a connecting tunnel under the railway, a second excavation was examined, where what appeared to be a triangular pocket of sand, though only one side could be seen, extended to the base of the workings. The depression here is no doubt of pre-Glacial origin, and the sand of the same age as that at Hillmorton.

There was no time for a detailed examination of this extensive section, and very little for the collection of fossils; but those who carried away large specimens of *Lima gigantea* no doubt quite realised the fact that fossils were to be found by the time they reached Rugby Station.

Lieut.-General McMahon, on behalf of the Association, thanked Mr. Edyvean-Walker for his courtesy and hospitality.

RUGBY AND NEWBOLD CEMENT WORKS.—From the last section a walk of about a mile brought the company to the Rugby and Newbold Cement Works. This excavation shows a face very much resembling the one at New Bilton, viz., frequent alternations of clay or shale and limestone, giving a strikingly banded appearance to the section, which, judging by this and the fossils seen, evidently belongs to the *Bucklandi*-zone. The chief point of interest here, however, was the sharp anticline shown on the north-eastern side of the pit. Mr. A. M. Hurst, by whose courtesy the section was examined, said that this anticline had been traced for about a mile, that the stone in it was not only more difficult to get, but when got was very inferior in quality for cement-making purposes—"the virtue had been taken out of it." This, of course, rather points to its being due to some sudden



LOWER LIAS LIMESTONE, SHOWING ANTHLICK TRENDING EAST AND WEST.
(Engraved, by permission, from the Memoirs of the Geological Survey.)

violent movement, but bearing in mind the sharpness of the curves, and their small lateral extension, it was considered it could not be due to upheaval from below, but rather indirectly to relief of pressure from above. Some photographs were taken of the anticline. The plate which is here reproduced is from Mr. H. B. Woodward's "Jurassic Rocks of Britain" (vol. iii, p. 164, *Mem. Geol. Survey*), kindly lent by the Director-General of the Geological Survey. It is from a photograph by Mr. J. D. Paul, and shows the anticline rather better than it can be seen now. A considerable quantity of water percolates through the limestones in the lower part of the excavation ; Mr. Hurst said about 12,000 gallons per hour.

From the Newbold Quarry a walk of about a mile brought the party to Rugby Station, where a well-earned meal was partaken of. Lieut.-General McMahon proposed a vote of thanks to the Director, which was carried unanimously. The return journey to London was made by the 6.47 train from Rugby.

NOTE.—Since the Excursion on May 7th I have been reading two papers, the titles of which stand first in the list of references below, and these lead me to believe that a good portion of the plateaux to the west of Hillmorton, embraced by a curve extending round to near Rugby station, is made up of the Brown Boulder Clay, and that this clay may have been deposited in a kind of bay out of the main track of the water.

B. THOMPSON.

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NOVEMBER, 1898.]

EXCURSION TO ALDEBURGH, WESTLETON, AND DUNWICH.

WHITSUNTIDE, MAY 29TH TO JUNE 1ST, 1898.

Directors: W. WHITAKER, F.R.S., PRES. G.S.; F. W. HARMER, F.G.S.; AND E. P. RIDLEY, F.G.S.

Excursion Secretary: BEDFORD MCNEILL, A.R.S.M., F.G.S.

(*Report by F. W. HARMER.*)

THE members left Liverpool Street Station on Saturday, May 29th, by the 11.45 a.m. train for Aldeburgh. On arrival, they proceeded to the Brudenell Arms Hotel, the headquarters.

A short excursion was made during the afternoon to the hamlet of Slaughden, half a mile south of Aldeburgh, to inspect the damage caused by the high tide of November, 1897.

It will be seen by reference to the map (Fig. 1) which, with other illustrations, has been reprinted from a paper by the writer,* by the kind permission of the Council of the Geological Society, that the river Alde approaches Slaughden at right angles to the coast, and the estuary, of which the present stream is the shrunken representative, must formerly have communicated with the sea in that direction. The travel of the beach, which on the eastern coast of England is from north to south, that is, in the direction of the currents attending the flowing tide, caused, however, the accumulation of a bank of shingle across the mouth of the estuary, and this bank continuing to increase in the same direction, gradually shifted the outfall to the south. At present the river Alde enters the sea at a place called Shingle Street, 8 or 9 miles from Aldeburgh, running parallel to the coast between the two places, a narrow belt of shingle-beach and salt marsh only intervening.

The high tide referred to transferred great quantities of shingle from the seaward to the landward side of the bank, rolling the pebbles over its crest, shifting the position of the bank westward, and causing it to make in places great inroads on the adjoining marshes. A number of buildings that stood immediately behind the bank were wrecked or damaged by its advance.

It is a hundred years since the poet Crabbe, then Rector of Aldeburgh, prophesied such a calamity in the following lines, appropriately quoted by Mr. Monckton from "The Village":

Till some fierce tide, with more imperious sway,
Sweeps the low hut, and all it holds, away.

One of the principal objects of the excursion to the Aldeburgh district was an examination of the zone-theory of the late Sir

* *Quart. Journ. Geol. Soc.*, vol. liv, p. 308, 1898.

Joseph Prestwich, the correctness of which has recently been challenged by the writer.* It has been held by all authorities to the present time that the Coralline Crag may be divided into a lower portion, composed of whitish, incoherent, calcareous sands, with frequent beds of shells, and an upper bed of indurated ferruginous rock. Prestwich adopted these divisions, but he believed that the lower part of the formation might further be separated into five distinct and continuous zones, representing great physiographical changes, including a gradual submergence of the Crag area to a depth of 500 or possibly of 1,000 feet, and alternations of climate by which at one stage the winter temperature of Northern Europe became sufficiently cold to bring floating ice from Scandinavia or the Ardennes to the shores of England. The writer has given in the paper already referred to the reasons which induce him to differ from these views. So far from admitting that the Coralline Crag can be divided into a number of zones, he now believes that the distinction between the shelly sands of Gedgrave and Sudbourne, and the ferruginous rock of Iken and Aldeburgh, is more apparent than real, and that the one is merely an altered condition of the other. With the exception of that of the basement bed, the material of the Coralline Crag is practically identical throughout, being almost entirely organic, formed of the comminuted remains of polyzoa and mollusca, with seams of perfect specimens of such organisms, and it must all, therefore, have originated under similar conditions; probably as a bank, in water of no great depth, parallel to the western shore of the Crag sea, and at no great distance from it. The molluscan remains are, with very few exceptions, the drifted shells of dead animals only, differing in this respect from the contemporaneous *Isocardia*-beds of Antwerp, which represent an undisturbed sea-bottom, the lamellibranchiate fossils of those beds being always found double, and never arranged in layers as in the Crag. It seems probable that the Coralline Crag banks were due to currents from the south-west flowing through a strait that connected the North Sea with the English Channel, which deposited little sediment where they ran strongly, but swept up from the sea-bottom the shells of mollusca living on it, depositing them afterwards in comparatively sheltered situations where the influence of the current was less felt.† Similar conditions now obtain off the coast of Antrim and at the southern end of the Isle of Man. An interesting proof of the identity of the two kinds of Coralline Crag was pointed out in pit No. 27, at the Brick Kiln Farm at Iken, visited on the 30th (see Map, p. 435), where a lenticular patch of the deposit in its unaltered condition, crowded with perfect shells like those of the sands at Gedgrave and elsewhere, occurs in the midst of a mass of the indurated

* *Quart. Journ. Geol. Soc.*, vol. liv, p. 308, 1898.

† The writer's views as to the geographical conditions under which the Coralline Crag may have originated are shown in the accompanying map (Fig. 2).

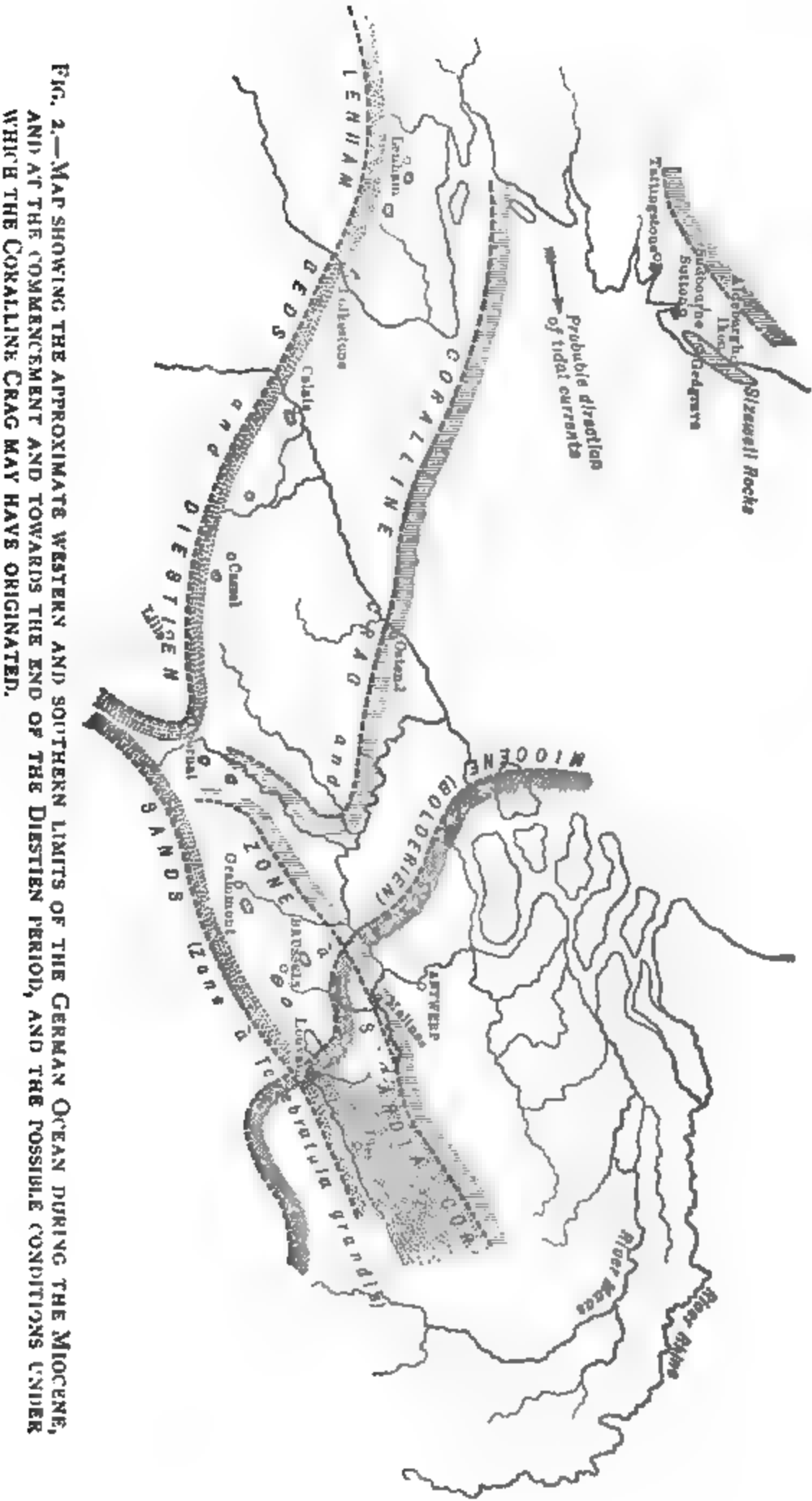


FIG. 2.—MAP SHOWING THE APPROXIMATE WESTERN AND SOUTHERN LIMITS OF THE GERMAN OCEAN DURING THE MIOCENE, AND AT THE COMMENCEMENT AND TOWARDS THE END OF THE DIESTIEN PERIOD, AND THE POSSIBLE CONDITIONS UNDER WHICH THE CORALLINE CRAG MAY HAVE ORIGINATED.

which has at the same time dissolved a portion of the g usually present in the shelly sands, and produced the fe and indurated condition of the altered Crag.

In pit No. 24, seams, a few inches in thickness, of ing polyzoa were noticed, extending horizontally ac section. It is suggested that these seams, which occur only, were due to the temporary diversion of currents, the accumulation of comminuted material ceased for certain spots, so that polyzoa could there establish th but they would afterwards be smothered and unable to e the returning currents brought over them again a new the fine calcareous mud.

At pit 25, now obscure, the position of the overly Crag was pointed out, and at the disused brick-field, 26 of Chillesford Clay was observed at one part of the secti

Monday, May 31st, was devoted to the examinatio exposures near Aldeburgh. Commencing the day's exc the pumping-station of the Water Works Co., where the ments for supplying the town with water were explained, visited successively pits 30, 34, 31, and 33, where a n specimens of polyzoa, some echinoderms, and many mollusca were obtained. Mr. P. F. Kendall pointed years ago * that the preservation of the polyzoa, and mollusca such as *Pecten*, *Mytilus*, and *Terebratula*, indurated Crag was due to the fact that the shells organisms are composed of carbonate of lime in the calcite ; aragonite, of which the tests of most mollusca being more readily acted on by water containing carboni

At the Aldeburgh brick-pit, where the section wa graphed, a fine exposure of the laminated clays of the ford Beds was seen. It was pointed out that t

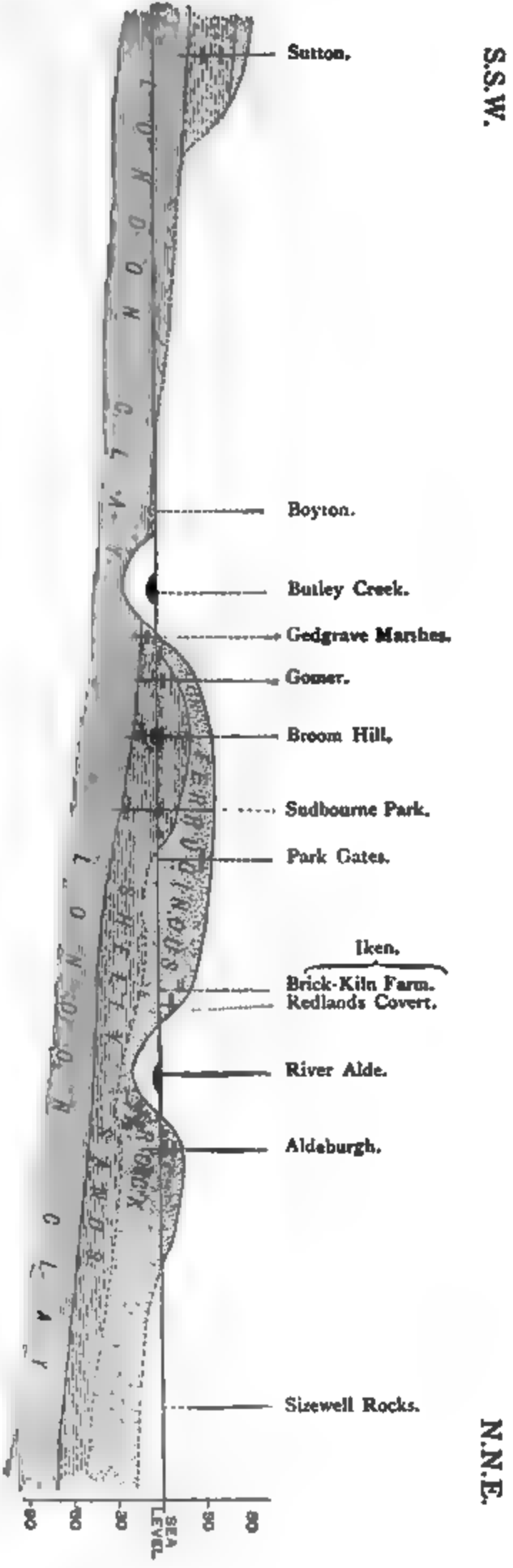


FIG. 3.—SECTION SHOWING THE STRUCTURE OF THE CORALLINE CRAG (ACCORDING TO THE PRESENT WRITER) AND THE PROGRESSIVE DIP TO THE N.N.E. OF ITS JUNCTION WITH THE LONDON CLAY.
The thick straight bars — indicate the position of the seams of large shells. The more recent beds are omitted.
(Reprinted by permission from *The Quarterly Journal of the Geological Society*.)

The section (Fig. 3) shows the structure of the Coralline Crag according to the writer's views. From borings recently made by him, which are shown in the section by vertical lines, it appears that the formation dips regularly to the north between Gedgrave and Sudbourne, as it does from Sutton to Gedgrave. It is about 60 feet in total thickness at Sudbourne Park, where the unaltered shelly sands and the upper ferruginous rock bed are both exposed. At Aldeburgh and Iken the rock bed only is visible.

A pleasant interlude to the more serious business of the day was a visit to the garden of the hospitable Chairman of the Aldeburgh Water Works Co., Mr. Jas. Flintham, where refreshments were kindly provided, a compliment which was happily acknowledged by Mr. E. T. Newton in an appropriate speech.

The day's excursion was brought to a close by a visit to the ancient Town Hall, a quaint and interesting building of the Tudor period, where some old maps of Aldeburgh are preserved.

The pit of Norwich Crag formerly existing near the Gas Works is, unfortunately, no longer accessible.

After dinner, on the motion of Mr. E. T. Newton, votes of thanks to the Directors and to Col. S. W. Smythe and Mr. Joseph Flintham were passed with much enthusiasm.

Tuesday, June 1st, carriages were provided to take the party to Westleton and Dunwich. The route led over the higher ground, covered with the Middle Glacial Sands and the overlying Chalky Boulder Clay; but as, unfortunately, rain fell during this part of the journey, no opportunity of examining these deposits could be found. Soon after reaching Westleton, the weather improved, and a visit was paid to the famous gravel pits on the Heath, first described by Prestwich. The beds there shown are composed almost wholly of flint, as is the shingle beach of Slaughden, but they contain also an insignificant percentage of small pebbles of quartz, jasper, and lydian stone. These gravels may be traced to the cliff at Dunwich, where they rest on the Crag sands, and, in the writer's opinion, to Henham, Halesworth, Southwold, and still further to the north. Mr. A. E. Salter, who has paid much attention to the subject, observed, however, that in his opinion some at least of the Southwold gravels are of different age. According to Prestwich, the Westleton Beds agree lithologically with the gravels which fringe the northern side of the Thames Basin, the latter being probably drifts arranged round the various gaps in the high ground of the district. Mr. H. B. Woodward observed that no fossils, belonging to the formation, had ever been found in the Westleton Shingle of Westleton, and he regarded the deposit as forming part of the "Middle Glacial" beds of East Anglia.*

* See *Geol. Mag.*, 1882, p. 455, and 1896, p. 357. The specimens referred to by Prestwich, *Quart. Journ. Geol. Soc.*, vol. xlv, p. 96 (footnote), were in my opinion procured from the Norwich Crag beneath the Westleton Shingle—H. B. W.

At Dunwich the party was met by Mr. Ed. Lingwood of that place, whose picture in this year's Academy has been much admired, both from an artistic and a geological point of view. Guided by him, a short cut was taken across some fields to the cliff, where an unusually good section presented itself, thanks to the high tide of last autumn. The Westleton Beds are shown cutting into "the unfossiliferous sands of the Crag," here decalci-

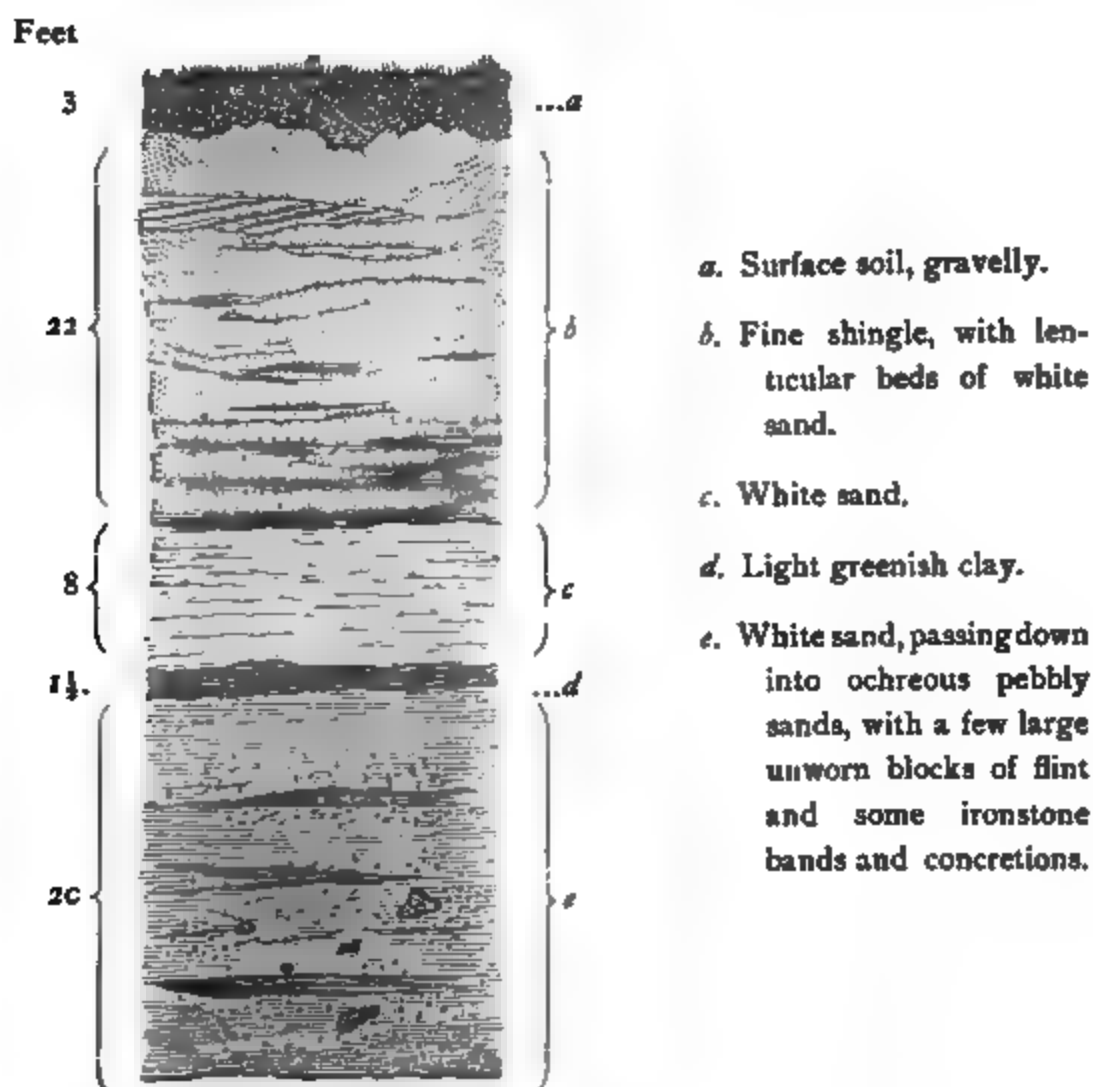
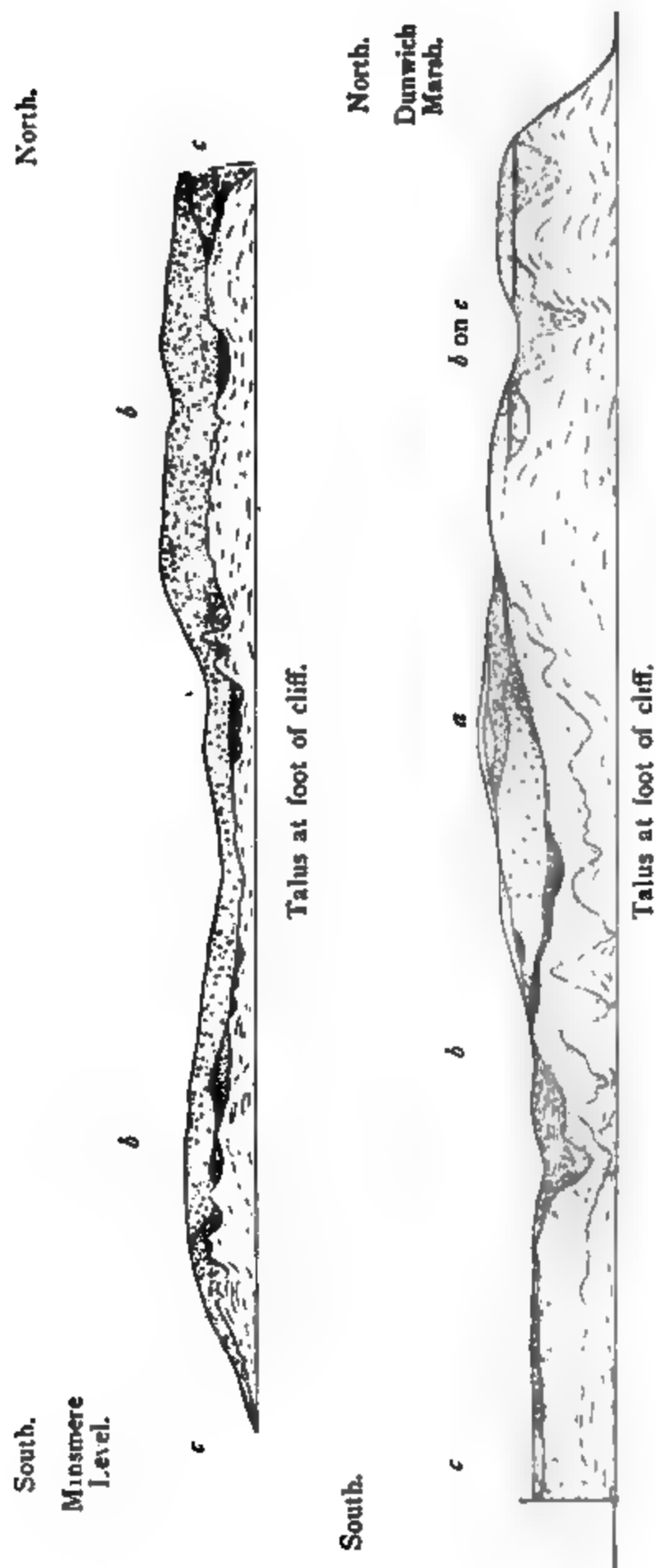


FIG. 4.—GENERAL SECTION OF THE WESTLETON BEDS,
WESTLETON COMMON.—*Prestwich.*

(Reprinted by permission from *The Quarterly Journal of the Geological Society.*)

fied by infiltration, and for the most part stained a bright orange colour. The lower part of the Crag, in an unaltered condition and full of fossils, is now well exposed at the base of the cliff, and it is to be hoped that collectors will not lose the opportunity of adding to the list of mollusca from this part of the Norwich Crag series.

After lunch, many of the members visited Mr. Lingwood's studio, and inspected his collection of coins and a varied



- a. Glacial Drift, Boulder Clay, sand, and loam.
- b. Pebbly Series.
- c. Crag for the most part decalcified.

FIG. 5. SECTION OF THE CLIFFS NEAR DUNWICH.—IV. Whitaker.

(Reprinted, by permission, from the *Journal of the Geological Survey*.)

assortment of articles found on Dunwich beach, and many other objects of interest.

A discussion ensued between Mr. Whitaker and the writer as to the relation of the Norwich Crag of Dunwich to the Red Crag, the former gentleman being disposed to regard the two deposits as more or less contemporaneous. In opposition to this view, it was urged that whereas the different stages of the Red Crag are characterised by a gradual disappearance of many of the extinct and southern species present at Walton-on-the-Naze, the oldest part of that formation, a number of them lingering on until the latest or Butley stage, that these forms had, with but few exceptions, disappeared altogether from the North Sea before the deposition of the Norwich Crag. The fauna of the latter presents a more decidedly modern and more boreal facies than does that of the Red Crag, and its characteristic species are fewer in number. The Norwich Crag beds contain, moreover, abundantly one arctic form, *Astarte borealis*, which has never been found in the Red Crag, and another, *Tellina lata*, which is exceedingly rare in the latter formation.

At Southwold, only four miles from Dunwich, a boring showed that the Crag extends to a depth of more than 100 feet below the sea level, and that it has a total thickness of 147 feet. The fossils obtained from this boring were all distinctly of the Norwich Crag type, and there is no evidence, either at Southwold or elsewhere in the district, that beds of Red Crag underlie those of Norwich Crag age. The latter, however, belong to the same set of conditions as the former, marking merely a more recent stage of the newer Pliocene period. In the writer's opinion the beds of the Upper Crag are arranged for the most part in horizontal rather than in vertical sequence, and are the marginal accumulation of a sea gradually retreating northwards, in consequence of the earth movements traced out in his paper on the Pliocene deposits of Holland.*

A walk along the beach towards the inn showed, *inter alia*, the remains of an old well, a relic of the once important town of Dunwich, and a small patch of almost decalcified Chalky Boulder Clay.

After lunch at the Barne Arms, carriages were again in request, and Darsham Station was reached in good time for the train for London, bringing only too quickly to a close an exceedingly pleasant and successful excursion.

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ORDINARY MEETING.

FRIDAY, MAY 6TH, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

Miss G. E. Robinson, John W. Grime, and Thomas Draper were elected members of the Association.

A paper was read by Mr. Horace B. Woodward, F.R.S., F.G.S., entitled “Notes on Skye,” and was illustrated by lantern slides, maps, and specimens.

Mr. A. Strahan, M.A., F.G.S., then gave a lucid account of his observations in Lapland, dealing more especially with the Raised Beaches and with the glacial phenomena of Palæozoic and Pleistocene age in the Varanger Fjord. His remarks were illustrated by lantern slides.

ORDINARY MEETING.

FRIDAY, JUNE 3RD, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The following were elected members of the Association:—D. A. Louis, Miss Mary S. Johnston, Malcolm Poignand, M.D., and Martin A. C. Hinton.

A paper was read by Mr. A. Smith Woodward, F.L.S., F.G.S., on “Fossil Sharks and Skates, with special Reference to those of the Eocene Period.”

EXCURSION TO GODALMING.

SATURDAY, JUNE 11TH, 1898.

Director: THOMAS LEIGHTON, F.G.S.*Excursion Secretary:* A. C. YOUNG, F.C.S.*(Report by the DIRECTOR.)*

THE party arrived at Godalming Station at 3.30 p.m., and walked at once to Busbridge Park. The Director stated that just thirty years ago the Association published Mr. C. J. A. Meÿer's paper on the Lower Greensand of Godalming. The chief facts upon which the author of that paper relied would be examined during the excursion, and although no publication had brought greater credit to the Association, the present occasion was in fact the first official visit to the district. The Lower Greensand country to the south of Guildford, about Littleton and Chilworth, also dealt with by Mr. Meÿer in his paper, has frequently been visited by the Association. The relations of the different horizons upon which Mr. Meÿer relies are, however, not now well shown there, and the geology of that district is complicated by an anticlinal fold. In the district to the south of Godalming the various horizons can be examined in succession between the town and the escarpment of the Lower Greensand. Throughout this area the normal dip is to the north in conformity with that of the Weald axis, but near Godalming some local southerly dip occurs, so that the surface of the dip-slope between Hambledon and Busbridge is almost entirely occupied by the Bargate and underlying so-called Sandgate Beds.

The party entered Busbridge Park by the public foot-path, on the right hand of which, over the lower lake, a good section of Bargate Stone, with underlying light-coloured sands, containing Bargate pebbles, was examined. Some specimens of *Terebratella fittoni*, Meÿer, were seen in the stone and sands, and the Director stated that he had never visited the locality without finding a few. The spring which supplies water to the lake was then examined, and the proof thus afforded of the presence of clay beds below, insisted upon. Passing along the north side of the lake, the lane section to the west of Busbridge Park, on the northern slope of the same valley, was next visited. This section shows an extensive thickness of the Bargate Stone and Pebble Beds, with the usual indications of clay below (springs). Specimens of *Terebratella fittoni* were found in the Pebble Sands, and the presence of chert, compact building stone, and other features of the beds were pointed out. The party then walked south and along the valley to Tuesley, noting the continued outbreak of springs on the way. The small quarry at the

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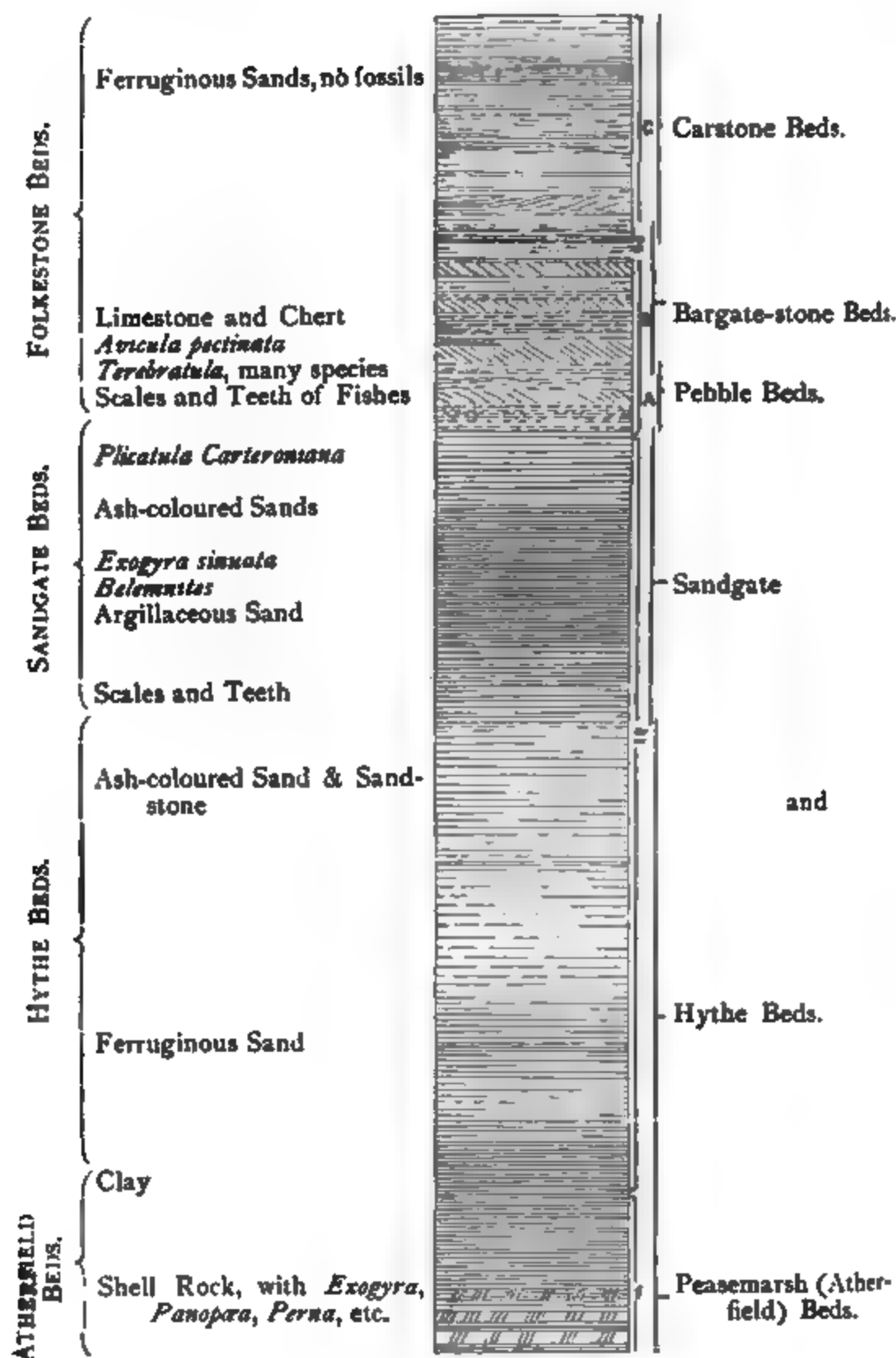


FIG. 1.—VERTICAL SECTION OF THE LOWER GREENSAND AT GODALMING.—C. J. Meyer.

Scale—80 feet to 1 inch.

roadside near Tuesley, rendered celebrated by Mr. Meÿer's work therein, was next examined—the bed at the bottom of the section from which most of the fossils were obtained is not now to be seen, owing to the rubbish which has accumulated. The size of the pebbles in the stone beds, and the extreme false bedding, were pointed out here. A small collection of derived fossils, including saurian teeth, fish vertebræ, and teeth of *Acrodus*, *Gyrodon*, *Hybodus*, *Lamna*, and *Lepidotus*, from Godalming and the near neighbourhood was exhibited by Mr. Coomara Swamy.

The party then took the field paths direct to Hambledon, where, in the hollow lane leading through the Lower Greensand escarpment, the clay beds which throw out the springs at Busbridge, are seen over the sands of the Hythe Beds, which again overlie the Atherfield Clay. These "clay" beds are of the kind usually recognised as Sandgate Beds when they occur at this horizon. They are clayey sands, with thin layers of clay, sometimes almost sandy clays, just sufficiently impervious to stay the percolation of water. Above them are some light-coloured sands and sandstones without pebbles, which Mr. Meÿer also classes with the Sandgate Beds. Below the argillaceous beds are the iron sands of the Hythe Beds becoming red below as the Atherfield Clay is approached—otherwise quite of the usual character. Before leaving this fine section the Director distributed amongst the party reprints of the vertical sections of the Lower Greensand between Dorking and Tilburstowhill (Fig. 2), from his paper upon that district, which the Council of the Association had prepared for the purpose. The Director asked the party to compare the position of the Busbridge and Hambledon clayey beds with that of the Fuller's Earth at Nutfield and Redhill, and to say whether, if the Busbridge and Hambledon clays were of Sandgate age, they could possibly lie upon the same horizon as the Nutfield Fuller's Earth, when the former were below the Pebble Beds, and the latter above them. Last year, at Redhill, this question was referred to at the excursion to that district, and in reply to the report of that excursion it was now pointed out, that whilst the Nutfield Fuller's Earth is a local deposit, fully important enough to justify anybody "in considering it a distinct division," nobody is justified in stating that division to be the Sandgate Beds, which occur, if at all at Nutfield, upon a lower horizon. The clayey beds of the Godalming district and of the Dorking district (both below the pebble beds) are very similar in lithological character and *mode of deposition* to the Sandgate Beds of Sandgate, whilst the Fuller's Earth is totally different to all three in both particulars. At Sandgate, Dorking, and Godalming, the origin of these beds must be the same, that is, the deposits are due to the occasional influx of muddy sediments during a period of the deposition of sand. The origin of Fuller's Earth has never been fully explained. Mr. Meÿer refers it to atmospheric

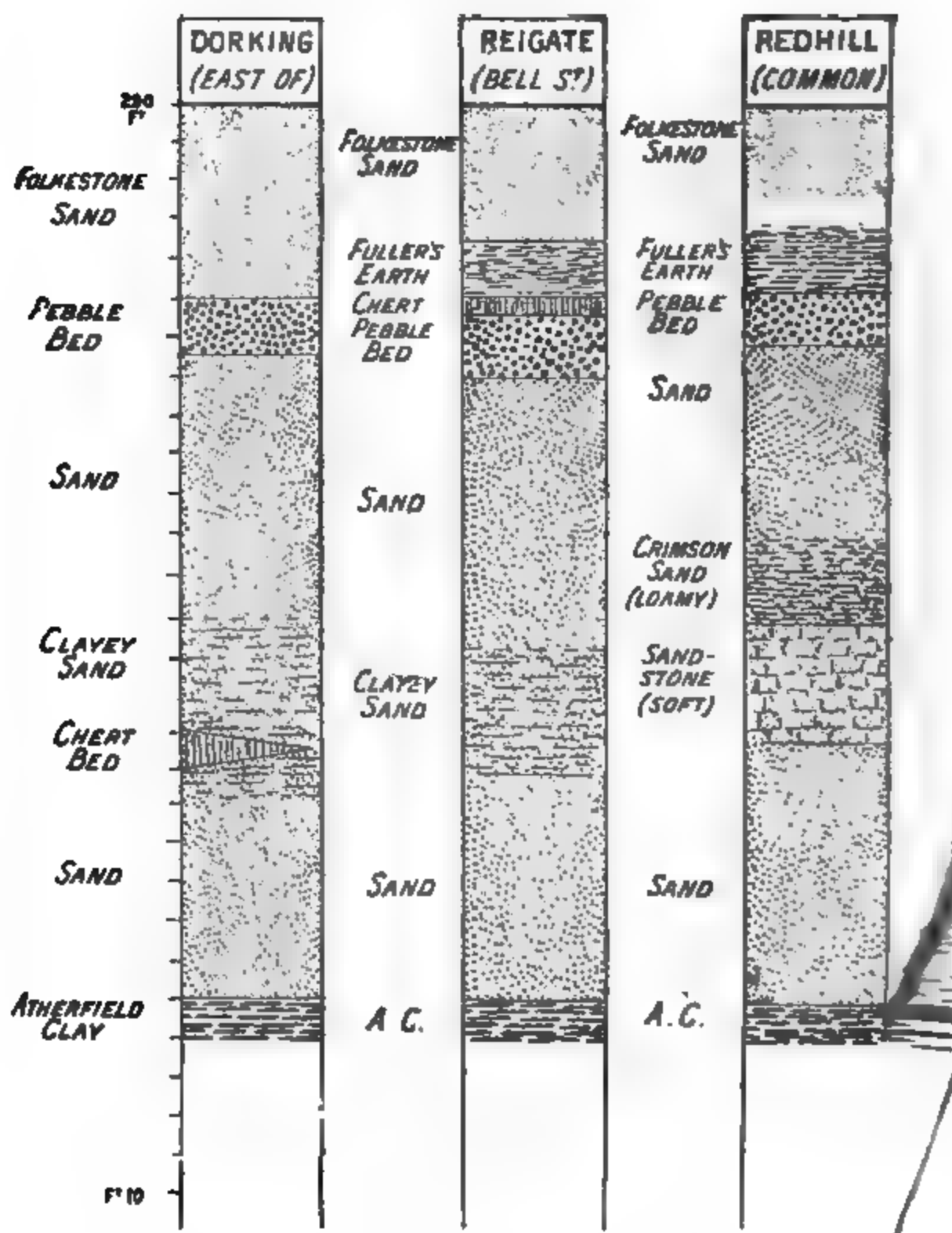
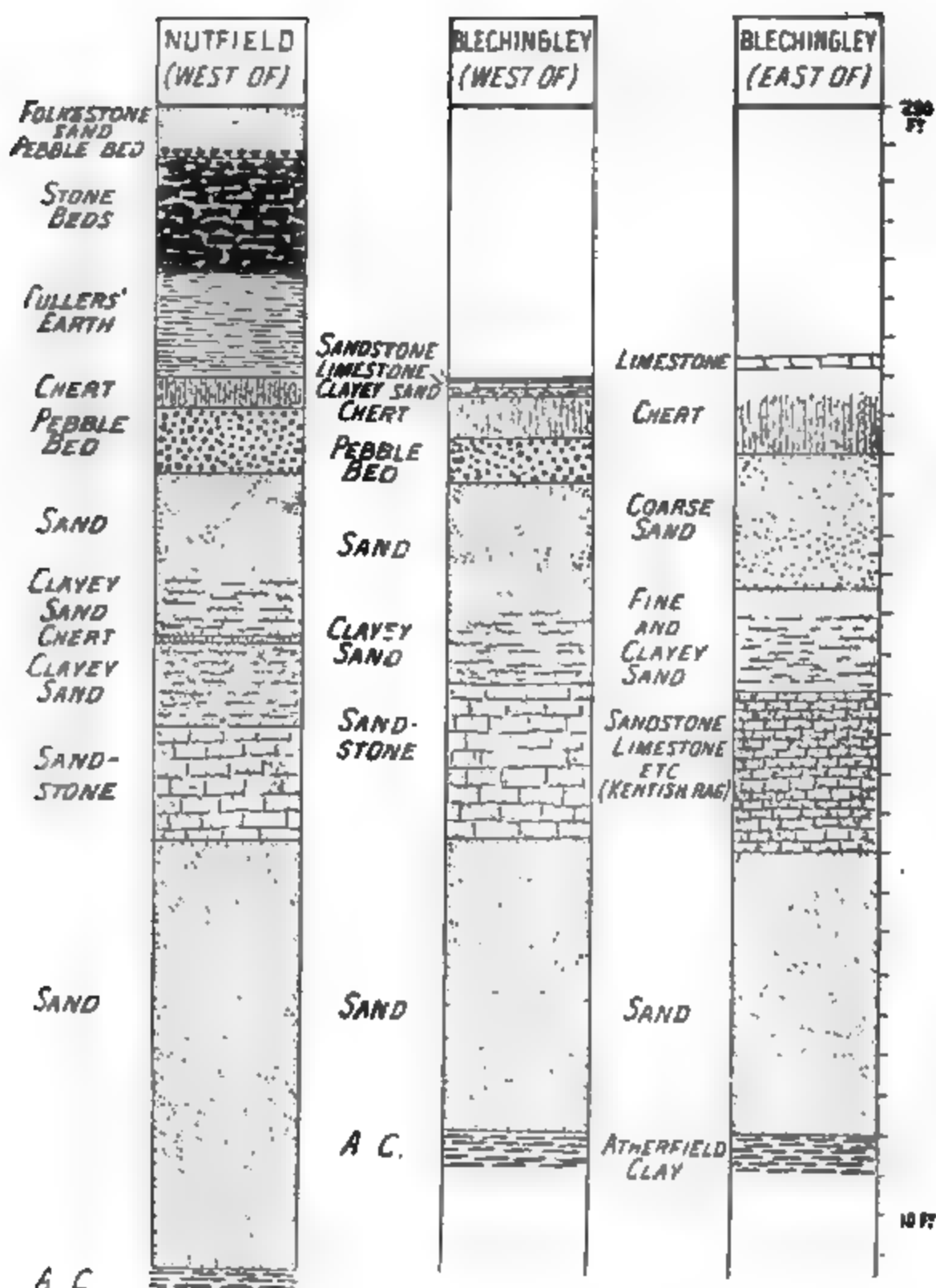


FIG 2.—VERTICAL SECTIONS OF THE LOWER GREENSAND

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BETWEEN DORKING AND TILBURSTOWHILL — *T. Leighton.*
the Quart. Journ. Geol. Society.

dust falling into extremely still water—a theory quite in accord with the resulting deposit, but requiring a considerable amount both of dust and time.

The party then returned northwards to Godalming, examining several sections along the road, particularly one near Busbridge Park, showing the junction of the Bargate Stone and Folkestone Sand, the latter in its lower part characterised here by some remarkable beds of Carstone.

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EXCURSION TO CROWBOROUGH.

SATURDAY, JUNE 18TH, 1898.

Directors: G. ABBOTT, M.R.C.S., AND R. S. HERRIES, M.A.,
SEC. G.S.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by R. S. HERRIES.*)

THE party, which numbered between forty and fifty, left London Bridge Station by the 12.25 train for Eridge. On arrival they walked southwards to Boarshead, where, by kind permission of Mrs. Gebhardt, they inspected the natural rocks which stand in the grounds of her house, known as “The Rocks.” There are here two groups of rocks, the “Upper” and the “Lower,” but whether the latter, which are at a somewhat lower level and several hundred yards to the north, belong to a lower horizon does not seem quite clear, the general dip of the bed being to the north. The rocks themselves, as Dr. Abbott pointed out, are of the same character as the High Rocks, Eridge Rocks, and the other well-known examples in the neighbourhood, showing the same vertical sides, the undercutting, and the honey-combing, noticed by the Association on previous excursions. They are, however, according to the mapping of the Survey, in the Ashdown Sands; most of the others being in the Tunbridge Wells

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Sands. Mr. Herries suggested that some revision of the mapping of this district might be found necessary, and he drew attention to a fault which was marked on the newest edition of Sheet 5 running E. and W., just N. of Boarshead Street. The Wadhurst Clay was here represented as faulted down against the Ashdown Sands. Should the rocks turn out to be Tunbridge Wells Sand this fault would not be necessary, as the Wadhurst Clay would then crop out to the south in the natural order of succession. Dr. Abbott, however, suggested that the "Upper" and "Lower" rocks might be part of a small anticline, as there was evidence of the former dipping south. If this was the case, he thought the mapping was probably correct.

The road was then followed through Steel Cross, with a long, steady ascent to Crowborough Cross, where there are clay beds in the Ashdown Sands, now being worked for bricks. Turning to the right, a slight descent brought the party to a quarry near St. John's Church. At this point attention was drawn to the fine view to the north and west, bounded by the long line of hills forming the Lower Greensand escarpment. The wild character of the scenery in the direction of Ashdown Forest was also pointed out. Mr. Herries then made some general remarks on the structure of the country and on the elevation and denudation of the Weald, on the roof of which, so to speak, the party was now standing. The summit of Crowborough Beacon, just above them, was 803 ft. above the sea, the highest point of the Wealden Beds, and, though the lowest beds of the district—namely, the Purbeck (Ashburnham) Beds—were not here exposed, this was in reality the centre of the great Wealden dome. The beds dipped away from this centre in all directions, forming what was known as a quaquaversal dip. In the quarry near which they were standing they could see that the dip was to the north, while on the other side of the Beacon, in a quarry that would be visited later on, the dip was in a southerly direction.

The section was then examined and the dip pointed out. The beds consist of layers of white sandstone, with rubbly beds above and a clayey bed at the base. Stalk-like impressions occur, especially in the last-named bed.

The party then divided, a few of the more ardent geologists following Mr. Herries through the woods about a mile to a quarry on the south side of the hill on the common adjoining the golf links. Still in the Ashdown Sands the beds here occur in courses of sandstone with flaggy partings, and are worked for building stone. The dip is a little to the east of south, that is, as already stated, in a contrary direction to the beds near St. John's Church. No fossils were seen except plant remains, which are in great abundance though somewhat obscure. There is a fine view over the country to the south from this point. The majority of the members went straight to the top of the hill

to Starfield, the residence of Dr. Isaac Roberts, F.R.S., who had kindly invited the members to see his observatory and astronomical instruments. This was very much appreciated, and one and all admired the perfection of the various instruments, the elaborate fittings, and, above all, the beautiful photographs of nebulae which had been produced in this observatory.

After inspecting the prettily-laid-out grounds and admiring the view, the united party met at the Red Cross Hotel at Crowborough Cross, where Dr. Roberts entertained them to an excellent dinner, at the conclusion of which a hearty vote of thanks was passed for all his kindness. The road down the hill to Crowborough Station was then taken, and a visit paid to the brickfield of the Crowborough Brick and Terra Cotta Company. This was still in the Ashdown series, and showed a considerable thickness of clay overlain by sandy beds. In the clay there is much lignitic matter and some nodules of Clay Ironstone (Carbonate of Iron.) The station was then reached in time for the 8.21 train for London.

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EXCURSION TO SUDBURY.

SATURDAY, JUNE 25TH, 1898.

Director : J. W. GREGORY, D.Sc., F.G.S., F.Z.S.

Excursion Secretary : A. C. YOUNG, F.C.S.

(*Report by THE DIRECTOR.*)

THE country around Sudbury is an undulating plateau through which the Stour Valley has been eroded to two different levels. The river now flows past Sudbury along an alluvial belt, 80 feet above sea-level. Above this belt, at the height of 100 feet, is an old gravel-capped flood-plain, on one of the broadest fragments of which the town of Sudbury stands. The main substratum of the district is Chalk, covered by thin sands belonging to the Lower London Tertiaries and a thicker sheet of London Clay. A few
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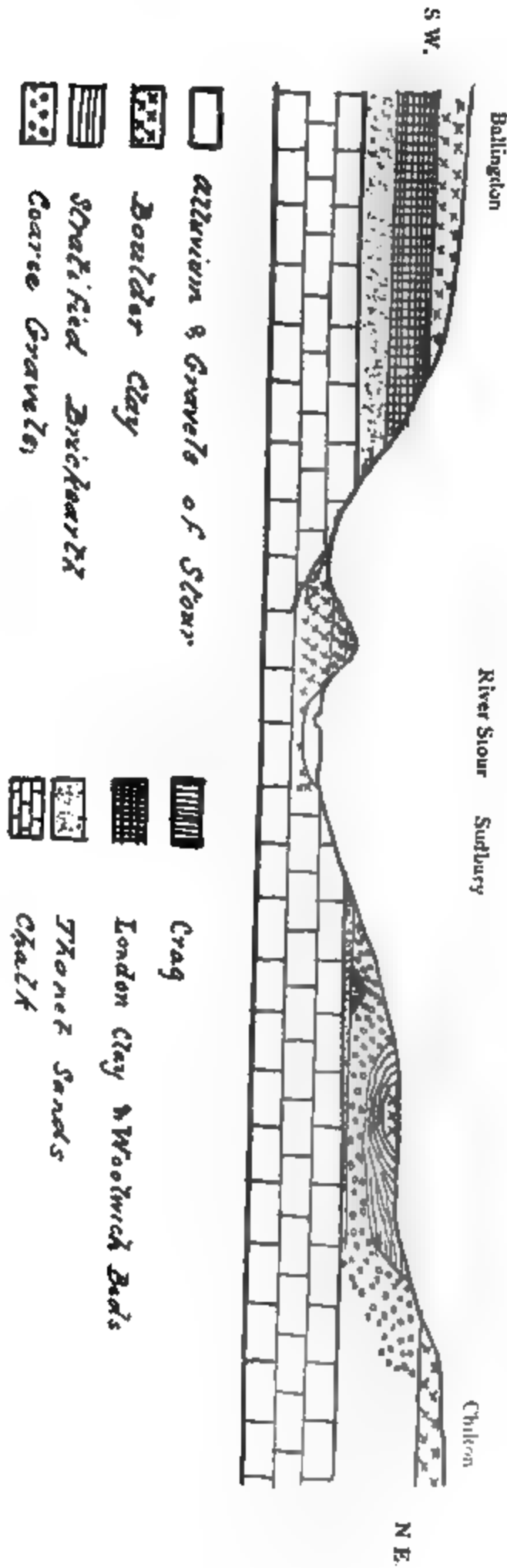


FIG. 6.—SECTION FROM BALLINGTON TO CHILTON
J. W. Gregory.

patches of Crag rest upon the Eocene beds. The whole series is covered with a mantle of drift, the examination of which was the main object of the excursion.

The members arrived at Sudbury at noon, and first went to the house of Dr. J. S. Holden, F.G.S., accepting his kind invitation to inspect his collection of local fossils. The party then crossed the Stour to the Essex side of the river and walked up to the sand-pit on Ballingdon Hill. The section showed a bed of white and buff sands covered by a seam of brown Boulder Clay. From the hill-side a good view can be obtained of the adjacent country. The general features are that the district is an undulating plateau at the level of a little over 200 feet, through which the Stour Valley has been excavated. The plateau may be regarded as a peneplain, and it is capped by Boulder Clay. The existing rivers have cut through the Boulder Clay to the London Clay, so that their courses are marked on the Survey Map by lines of brown, breaking across the broad wash of blue that represents the Boulder Clay. Inspection of the map, therefore, sufficed to convince members that the river system of the district is later than the age of the Boulder Clay. Not only is the Boulder Clay—with an exception to be noticed immediately—absent from the river valleys, but it is absent also from the higher hills in this part of Essex. The Danbury Hills, for example, rise like an island above the sheet of Boulder Clay which lies around their feet.

Whatever the agent was that deposited the Boulder Clay, it was an agent with a great horizontal expansion, but whose vertical range of action was very limited. The Boulder Clay and "Glacial Gravels" of Sudbury show none of the characters typical of the action of land ice, and the Director accordingly remarked that both the distribution and characters of the deposit were in harmony with the late Carvill Lewis's theory of its deposition in an extra-glacial lake. There is, however, one difficulty at Sudbury in this explanation. The Boulder Clay sheet of the plateau is at the level of about 200 feet, and is truncated along the hill-sides by the river-valleys. But in the second pit visited, that at the Grove, there is a deposit of Boulder Clay at the level of only 100 feet. The Director regarded this valley Boulder Clay as a different deposit from that of the plateau; but Rev. E. Hill, who was with the party at the Ballingdon Pit, and who knows the district well, regarded the two Boulder Clays as part of the same sheet. Mr. F. W. Harmer, however, agreed with the Director that the valley Boulder Clay was different from the plateau Boulder Clay, and he felt disposed to correlate the former with the lower Boulder Clay of Norfolk. Unfortunately the exact relation of the two Boulder Clays is not shown in the field, and lithological correlations are dangerous.

The valley Boulder Clay may be a remnant of an old Boulder

Clay which filled up the Stour Valley before the deposition of the plateau Boulder Clay; or it may possibly be later than the plateau Boulder Clay formed during the erosion of the present Stour Valley, and from materials obtained by the denudation of the plateau Boulder Clay.

In the Grove Pit foreign boulders, scratched blocks, and Jurassic fossils are not uncommon. Some of the boulders are of considerable size. The fossils that the Director had collected in the pit might all have come from the eastern and north-eastern counties. Among other fossils a good specimen of an ammonite has been determined by Mr. G. C. Crick as *Reineckia anceps* (Rein.).

From the Grove the party returned to the Suffolk side, and visited the group of pits to the east and north-east of the town. The first visited, viz., Mr. Green's pit, has been admirably described by Mr. J. E. Marr, whose views were explained. The contortions in the drifts were recognisable, though the section had been obscured by rainwash and weeds since Easter of the present year. The members generally agree that the aspect of the contortions suggested subsidence, and not lateral thrust.

The Alexandra and Victoria pits, which had been described by Mr. Whitaker, were next visited, and a series of sharks' teeth collected from the Crag pebble-beds. At Galley Hill the Boulder Clay was seen again, filling up the trough of a synclinal in the laminated brick-earths. It is possible that this Boulder Clay is not *in situ*, but is re-deposited Boulder Clay, for it contains seams and irregular patches of sandy loam. In the great pit at Chilton the brick-earths were seen again as a regularly-bedded, horizontal, laminated loam. The Director regarded this deposit as having been laid down in the quiet waters of a lake or backwater. In striking contrast to this fine sediment are the coarse, irregularly-bedded, torrential river-gravels of a pit at the western end of the Chilton fields.

After tea at Sudbury, a few remarks were made summarising the day's observations, referring to the extreme variability of the drift series, the absence of any trace of moraines and typical morainic material, and the difficulty of pointing to any one feature in the drifts as due to the direct action of local glaciers.

At the end of the day Mr. Potter proposed a vote of thanks to Dr. Gregory for the trouble he had taken in arranging this very interesting excursion, and to Mr. A. C. Young for acting as Excursion Secretary during the month of June. Both votes were carried by acclamation, and the party broke up after a most successful excursion—the party who travelled by the official train having been joined by several members of the Association at Mark's Tey or at Sudbury.

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EXCURSION TO KINGSWOOD AND WALTON-ON-THE-HILL.

SATURDAY, JULY 2ND, 1898.

Directors: W. WHITAKER, F.R.S., PRES. G.S., AND
W. P. D. STEBBING, F.G.S.

Excursion Secretary: BEDFORD MCNEILL, F.G.S.

(*Report by THE DIRECTORS.*)

THIS excursion was arranged to give members an opportunity of seeing some sections on the new Chipstead Valley line of the South Eastern Railway, which, when finished, will extend from Purley to Tattenham Corner on Epsom Downs.

The party assembled at Charing Cross Station, and travelled by the 12.56 train to Kingswood, up to which point the new line is already open for traffic. Leaving the station, the Directors led the way westward along the top of the cutting. The section showed in places a very irregular surface of Chalk covered by a thin bed of clay, in some places perfectly black, with unwater-worn flints. Above the clay there was a loamy and sandy bed with masses of pebbly gravel, probably a reconstructed wash from Eocene beds. Near the entrance to the tunnel under Walton Heath, Mr. Whitaker pointed out a mass of fine white quartz sand from the Tertiary beds, left like a great saucer-shaped boulder in the loamy bed; its position, he explained, was due to piping in the underlying Chalk. No Eocene actually in place was to be seen at the eastern end of the tunnel.

On leaving this section, the party walked in a north-westerly direction across the corner of the Heath, following the line of the tunnel to a cutting which is in course of excavation. The following extremely interesting section was seen:

(1) Bedded sand and pebbles, probably Blackheath Pebble Beds, more or less rearranged. This pebbly bed lies with curved stratification on the underlying beds, but the curvature and the irregularities noticed are not wholly due to original irregularity of deposition, but partly to the subterranean dissolution of the Chalk beneath.

(2) Under the pebbly and sandy beds a little pink and greenish clay or loam from the base of the Woolwich and Reading Beds was seen; it was not *in situ*, but had been slightly moved owing to pipes in the Chalk below.

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Mr. Whitaker expressed the opinion that the Woolwich and Reading series has never had any great thickness here, although they are fairly well developed just to the west, at Headley, but that the Blackheath Beds had originally almost rested on the Thanet Sands, and he remarked that on the next Saturday the members would have an opportunity at Worms Heath of seeing the Blackheath Pebble Beds resting directly on the Chalk, all intermediate formations (except, perhaps, a trace of Thanet Sand), being there absent. He also commented on the extent originally of these pebble-beds southward from the main mass.

(3) Thanet Sand.—Great rounded bosses of this formation reached in places almost to the top of the cutting, the curves of the hollows between them being followed by the beds above, but the sections on the opposite sides of the cutting were very different. Mr. Whitaker remarked here on the difficulties of mapping a country of this kind and the uncertainty as to where a bed may begin or finish.

(4) At one place there was a small pinnacle of Chalk sticking up into the Thanet Sand, without the intermediate bed of green-coated flints; further north more Chalk was seen in the cutting showing good examples of pipes.

Leaving the railway the party walked across Walton Heath to some pits in sand and gravel. Dr. Hinde being called upon, stated that the members stood upon a plateau between the Rivers Wandle and Mole; and here, on the watershed of the former, they found a sheet of gravel at a level of 500 to 600 ft. above the sea. This gravel consists mainly of more or less rolled flints and pebbles from the Blackheath Beds, and contains green-coated flints from the base of the Thanet Beds, and a number of stones of irregular shape which came from the Lower Greensand Chert beds. These cherts were largely formed of sponge-spicules, and could be found *in situ* some two miles to the south of the gravel but separated from it by a valley 400 ft. deep. The valley could not have existed when the gravel was deposited. These deposits are the Southern Drift of Prestwich.

Mr. Whitaker asked if the chert might not come from the lower and the ironstone from the upper beds of the Lower Greensand. He said it was interesting to note that here we have chert, and elsewhere, in gravel of this age, ironstone, showing that one must not classify gravels solely by their mineral contents, and that two gravels may be of the same age and origin, though of different composition.

Mr. Stebbing mentioned that he had not found any ironstone here, but about a mile and a half to the south-west there was plenty to be seen on some ploughed fields. According to Mr. Salter the ironstone increases towards the river Mole, and came from Tertiary beds.

The President asked whether all agreed that when these

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EXCURSION TO KINGSWOOD AND WALTON-ON-THE-HILL.

SATURDAY, JULY 2ND, 1898.

Directors: W. WHITAKER, F.R.S., PRES. G.S., AND
 W. P. D. STEBBING, F.G.S.

Excursion Secretary: BEDFORD MCNEILL, F.G.S.

(*Report by THE DIRECTORS.*)

THIS excursion was arranged to give members an opportunity of seeing some sections on the new Chipstead Valley line of the South Eastern Railway, which, when finished, will extend from Purley to Tattenham Corner on Epsom Downs.

The party assembled at Charing Cross Station, and travelled by the 12.56 train to Kingswood, up to which point the new line is already open for traffic. Leaving the station, the Directors led the way westward along the top of the cutting. The section showed in places a very irregular surface of Chalk covered by a thin bed of clay, in some places perfectly black, with unwater-worn flints. Above the clay there was a loamy and sandy bed with masses of pebbly gravel, probably a reconstructed wash from Eocene beds. Near the entrance to the tunnel under Walton Heath, Mr. Whitaker pointed out a mass of fine white quartz sand from the Tertiary beds, left like a great saucer-shaped boulder in the loamy bed; its position, he explained, was due to piping in the underlying Chalk. No Eocene actually in place was to be seen at the eastern end of the tunnel.

On leaving this section, the party walked in a north-westerly direction across the corner of the Heath, following the line of the tunnel to a cutting which is in course of excavation. The following extremely interesting section was seen:

(1) Bedded sand and pebbles, probably Blackheath Pebble Beds, more or less rearranged. This pebbly bed lies with curved stratification on the underlying beds, but the curvature and the irregularities noticed are not wholly due to original irregularity of deposition, but partly to the subterranean dissolution of the Chalk beneath.

(2) Under the pebbly and sandy beds a little pink and greenish clay or loam from the base of the Woolwich and Reading Beds was seen; it was not *in situ*, but had been slightly moved owing to pipes in the Chalk below.

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Mr. Whitaker expressed the opinion that the Woolwich and Reading series has never had any great thickness here, although they are fairly well developed just to the west, at Headley, but that the Blackheath Beds had originally almost rested on the Thanet Sands, and he remarked that on the next Saturday the members would have an opportunity at Worms Heath of seeing the Blackheath Pebble Beds resting directly on the Chalk, all intermediate formations (except, perhaps, a trace of Thanet Sand), being there absent. He also commented on the extent originally of these pebble-beds southward from the main mass.

(3) Thanet Sand.—Great rounded bosses of this formation reached in places almost to the top of the cutting, the curves of the hollows between them being followed by the beds above, but the sections on the opposite sides of the cutting were very different. Mr. Whitaker remarked here on the difficulties of mapping a country of this kind and the uncertainty as to where a bed may begin or finish.

(4) At one place there was a small pinnacle of Chalk sticking up into the Thanet Sand, without the intermediate bed of green-coated flints; further north more Chalk was seen in the cutting showing good examples of pipes.

Leaving the railway the party walked across Walton Heath to some pits in sand and gravel. Dr. Hinde being called upon, stated that the members stood upon a plateau between the Rivers Wandle and Mole; and here, on the watershed of the former, they found a sheet of gravel at a level of 500 to 600 ft. above the sea. This gravel consists mainly of more or less rolled flints and pebbles from the Blackheath Beds, and contains green-coated flints from the base of the Thanet Beds, and a number of stones of irregular shape which came from the Lower Greensand Chert beds. These cherts were largely formed of sponge-spicules, and could be found *in situ* some two miles to the south of the gravel but separated from it by a valley 400 ft. deep. The valley could not have existed when the gravel was deposited. These deposits are the Southern Drift of Prestwich.

Mr. Whitaker asked if the chert might not come from the lower and the ironstone from the upper beds of the Lower Greensand. He said it was interesting to note that here we have chert, and elsewhere, in gravel of this age, ironstone, showing that one must not classify gravels solely by their mineral contents, and that two gravels may be of the same age and origin, though of different composition.

Mr. Stebbing mentioned that he had not found any ironstone here, but about a mile and a half to the south-west there was plenty to be seen on some ploughed fields. According to Mr. Salter the ironstone increases towards the river Mole, and came from Tertiary beds.

The President asked whether all agreed that when these

gravels were laid down, the valleys around did not exist, and also whether there was any general agreement as to the origin of the gravel; to which Mr. Whitaker replied that he thought there was a considerable difference of opinion as to the origin of the gravel.

On leaving this section the party walked through Walton village to the church, where the Norman lead font was inspected. Continuing the walk across the fields Frythe Park was reached, where Mr. and Mrs. Stebbing had invited the party to tea. After tea, the President heartily thanked the Directors of the excursion, and the members walked across Walton Heath to Kingswood Station in time for the 7.30 train to London.

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EXCURSION TO UPPER WARLINGHAM AND WORMS HEATH.

SATURDAY, JULY 9TH, 1898.

Director: W. WHITAKER, B.A.Lond., F.R.S., Pres. G.S.

Excursion Secretary: A. E. SALTER, B.Sc., F.G.S.

(*Report by* MR. SALTER *and* DR. G. J. HINDE, F.R.S.)

THE party left London by the 1.40 p.m. train, reaching Upper Warlingham Station at 2.15. Mr. Whitaker led the way to the pits at Whiteleaf, north of the station, where about 15 feet of chalky valley-gravel is being worked. Remains of Rhinoceros and Reindeer occur here, and a portion of a tooth of *Elephas primigenius*, was found by Dr. Johnston-Lavis during the visit. Dr. Hinde, at the request of Mr. Whitaker, gave an account of the composition of the gravel, and made special reference to the large blocks of conglomerate seen in the pit. Some of these blocks could be shown to have been derived from Tertiary beds higher up the valley but others of a more sandy nature had not been detected *in situ*. The party then proceeded to Worms
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Heath, where there is a fine section in an outlier of Blackheath Beds. Towards the base the pebbles had become cemented by iron oxide into a hard conglomerate. Sand occurred below the pebble beds, and between the two was a thin band of allophane; numerous specimens of this mineral were obtained. The amount of oxide of iron present gave the section a vivid red appearance. In spite of a long search, nothing beyond flint pebbles was found although on previous occasions a few quartzite pebbles of unknown derivation had been obtained by Dr. Hinde. Above the Blackheath Beds was to be seen a quantity of drift material, derived from Blackheath Beds and Thanet Sand. A short walk through a picturesque plantation brought the members to the edge of the dry Chalk valley, and the magnificent view there obtained was thoroughly enjoyed by all. A steep descent was made to the main road, and Upper Warlingham was again reached. Here the members enjoyed the hospitality of the Rev. T. T. Griffith, M.A., amidst the sylvan beauties which surround his home. Hearty votes of thanks to the Director and to the Rev. Mr. Griffith concluded an instructive excursion.

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EXCURSION TO SHEPPEY.

SATURDAY, JULY 16TH, 1898.

Directors: W. WHITAKER, F.R.S., PRES. GEOL. SOC., T. V. HOLMES, F.G.S., AND W. H. SHRUBSOLE, F.G.S.

Excursion Secretary: A. E. SALTER, B.Sc., F.G.S.

(*Report by THE DIRECTORS.*)

ABOUT forty members left London by the 9.56 a.m. train, arriving at Sheerness at noon, and drove thence to East End Lane, where the vehicles were left and the journey continued by the cliff path on foot. Near at hand was the only remaining Coast-guard Station of four which had been erected; the other three have been entirely swept away by the erosion of the coast, and their sites are now well out on the foreshore.

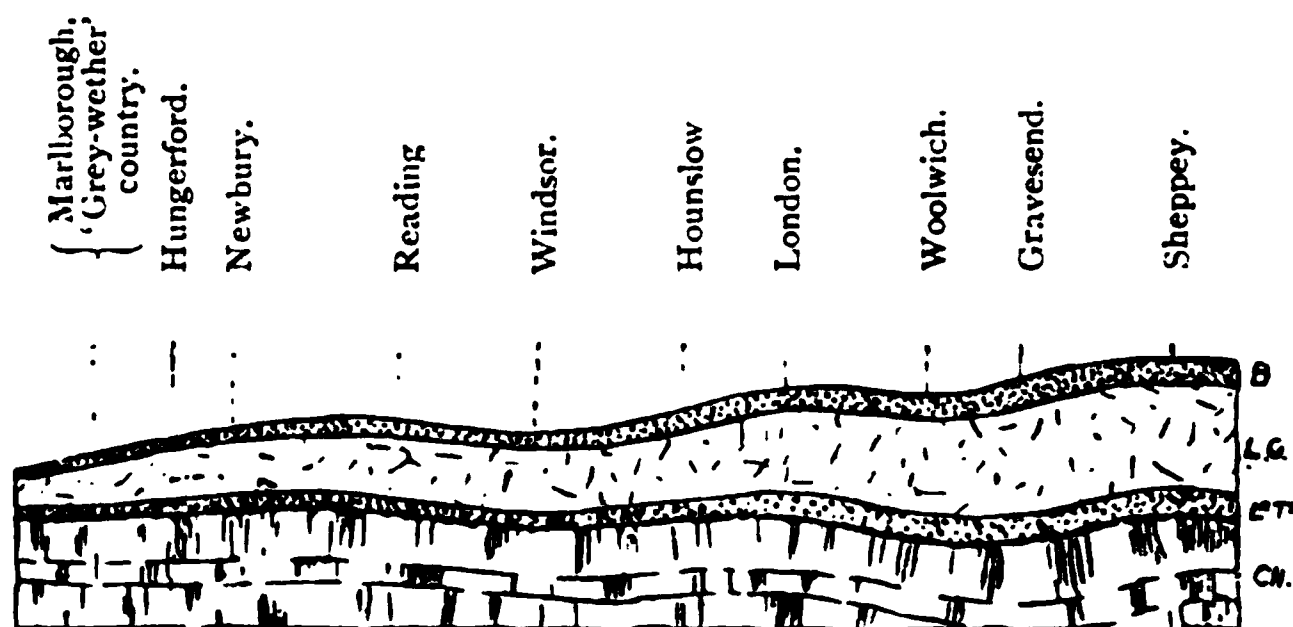
In the cliff section, above the London Clay, the Lower Bagshot Beds were seen, standing almost perpendicularly, and capped
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irregularly by false-bedded sand and gravel. Where slips had recently occurred the line of junction with the London Clay was very clearly defined. Although a passage bed is generally seen in sections elsewhere, a sharp line of demarcation has been observed in these cliff sections for many years.

At a spur-like projection of the cliff, Mr. Whitaker took the opportunity of drawing attention to the various strata to be seen in the cliffs.

On looking over the fields hereabout, the presence of gravel in considerable thickness could be noted by the stunted and unhealthy appearance of large patches of the growing crops.

At Hensbrook Gap the party descended to the beach. At the mouth of the gap a large heap of partially-decomposed pyrites



IDEAL SECTION OF LONDON CLAY (PRESTWICH).

B. Bagshot Series.

Lr. Ts. Lower Tertiaries.

L.C. London Clay.

CH. Chalk.

was seen. Its presence in that position showed that there is now no demand for iron pyrites as an article of commerce. It was pointed out that the heap probably represented many months of hard toil by the women who had transported the heavy material from a considerable distance, over the slippery shingle, in bags carried on their backs.

Passing eastward along the beach, a diligent search was made for fossils; but from some cause not easily ascertainable, the quantity found was much less than on former occasions. There were many logs of fossil wood bored by *Teredo*, and several of the party secured specimens of *Nipadites*; these are always in evidence, even when no other fossils are to be found. At Barrowsbrook was seen a small natural bridge formed by fallen masses of clay, beneath which the brooklet had cut its way. Just beyond this, and extending past Warden Point, the lower part of the cliff presented a precipitous face which could not be scaled,

so the ascent took place a little to the east of the point itself. When the old road was reached, the part of the churchyard which still remains intact was seen about 100 ft. below its former level, tilted at an angle of about 40° . The site of the church is now covered by the beach. The only vestige of the church remaining is a stone bearing an inscription in a cottage garden near by.

The vehicles were now made use of to convey the party to Minster, where a hasty survey of the interior of the Abbey Church was made. Mr. Parker discoursed on the local ecclesiastical history, to the general gratification of the members, and the party returned to Sheerness. A substantial meal was provided at the Royal Hotel, and afterwards the President moved a vote of thanks to the Directors of the Excursion, and especially mentioned some of the services which had been rendered to geological science by Mr. Shrubsole. The vote of thanks was carried by acclamation, and in reply, Mr. Shrubsole gave further information respecting some of the discoveries which had been alluded to.

The remarkable mineralised Diatoms* occurred in a zone (having a considerable range) near the base of the London Clay, and therefore only to be reached in Sheppey by deep excavation. Radiolaria,† in a pyritised condition, had also been found in clay from a well near Queenboro' Railway Station. The only freshwater shells, *Camptoceras priscum*,‡ known to occur in the London Clay he found in a septarian nodule. The skull and other portions of the skeleton of the toothed bird, *Argillornis longipennis*§ were found at different times among the shingle on the beach, unobscured either by limestone or pyrites. The immense skull of *Chelone gigas*|| (*Eosphargis gigas*) was enclosed in a septarian nodule, the outline of which furnished the only clue to something organic within. Interesting reference was made to its skilful exhumation at the British Museum, and the delight of Sir Richard Owen at finding such complete evidence of a gigantic Chelonian, the existence of which was foreshadowed forty years before by a small fragment of bone, on which the name had been bestowed.

The most recent discovery was the skull of another bird in 1897. Unlike the *Argillornis*, it was enclosed in a limestone nodule of oval form, at one end of which the base of the cranium was slightly exposed. The expert mason of the British Museum soon revealed what appears to be a perfect avian skull. A description of this interesting specimen is in course of preparation. As usual Mr. Shrubsole has added this skull to the National Collection at South Kensington. The Director concluded his remarks by the

* See *Journ. Royal Microscopical Soc.*, 1881.

† See *Quart. Journ. Geol. Soc.*, vol. xlv, 1889, p. 121.

‡ *Ibid.*, vol. xxxviii, 1882, p. 218.

§ *Ibid.*, vols. xxxiv and xxxvi.

|| *Ibid.*, vol. xlv; "Cat. Fossil Reptilia, Brit. Museum," part 3; "Owen's Palæontology," 2nd edition, pp. 317, 318.

statement that the first visit of the Geologists' Association to Sheppey in 1871, was made at his suggestion, and led him to become a student of geology.

Mr. T. V. Holmes called attention to some matters of interest in connection with the ancient physical geography of the district. Looking at the action of the sea, it became evident that the North Foreland stood out because of the superior hardness of the Chalk, while the softer Tertiary and later beds of Essex had been eaten away much more rapidly. Some years ago he discovered in a railway cutting close to Romford, the remains of an old silted-up stream-course, covered by Thames Valley Gravel. This stream, before the intrusion of the ancient Thames, had apparently flowed to the north-east and joined the Blackwater below Maldon, the valleys of the Mardyke and the Crouch having evidently come into existence at a much later date.* As regards the old deposits of the lower Thames, gravel and loam were shown on the Geological Survey Map extending from Southend to Burnham-on-Crouch, and thence to the mouth of the Blackwater at Bradwell. These beds were considered by Mr. Whitaker to be old Thames Valley beds, deposited when there was a considerable breadth of land east of them, where there is now sea. A chart of the Thames Estuary illustrated very strikingly a former state of things. In it could be seen a series of channels, separated by shoals and sandbanks, ranging from the Nore in a north-easterly direction, and evidently marking the positions of the Thames and Medway at former periods when the two rivers occupied independent valleys, east of what is now the coast of Essex, and entered the sea somewhere off Harwich. The shoals and sandbanks now separating the channels east of Essex, marked the planing down action of the sea on the higher ground once separating them, as the broad shoals north of Sheppey and Herne Bay indicated similar action on the soft strata of northern Kent.

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* See *Quart. Journ. Geol. Soc.*, vol. 1, p. 443, 1894, and *Essex Naturalist*, vol. ix. March-October 1896.

EXCURSION TO GRAVESEND.

SATURDAY, SEPTEMBER 10TH, 1898.

Director : G. E. DIBLEY, F.G.S.*Excursion Secretary* : A. E. SALTER, B.Sc., F.G.S.

(Report by THE DIRECTOR.)

THE party arrived at Gravesend (S.E.R.) about 3.30 p.m., and were met by the Director and a few other Members of the Association.

Messrs. Fletcher and Co.'s chalk-pit was first visited, and a halt made near the whitening works; attention was drawn to a large heap of rounded black flints, which might easily have been mistaken for shingle. These flints had been taken from the washing troughs in which the chalk is ground.

The Director remarked that fossils are very abundant in this district, and among the more important are those contained in the list of foraminifera and ostracoda published by Mr. F. R. Chapman, A.L.S., F.R.M.S., in the PROCEEDINGS, vol. xiii, p. 369 1894, from the same horizon in the Chalk at Swanscombe, $1\frac{1}{2}$ miles to the west, and the following: *Siphonia*, *Ventriculites radiatus*, *Pharetrosporgia*, *Parasmilia centralis*, *Goniaster* is abundant (usually very fragmentary), *Ophiura*? (obtained by the Director), *Echinocorys vulgaris*, *Echinoconus conicus*, and a small rounded variety; the high-crested form of *Micraster coranguinum* (which is exceedingly abundant) is typical of this horizon of the Upper Chalk, *Cyphosoma koenigi*, *Cidaris perornata*, *C. sceptrifera*, and *Bourgueticrinus ellipticus*. No *Marsupites* had been met with in this locality, though the quarrymen were supplied with plates of specimens to assist their search. *Serpula plexus* is often found in masses. The polyzoa of the district are being worked out by Dr. Arthur Rowe, F.G.S. Among other forms *Crania*, *Terebratula semiglobosa*, *Rhynchonella plicatilis*, *Ostrea*, *Pecten nitidus*, *Plicatula*, *Spondylus* (*Dianchora*) *latus*, *S. spinosus*, *Lima hoperi*, *Inoceramus*, and *Pleurotomaria perspectiva* may be mentioned. *Belemnitella quadrata* occurs near the base of the pits, and *B. vera* nearer the top. From the London Portland Co.'s pit the Director had obtained an *Ostrea* bearing the markings of the sutures of an *Ammonite*, also an *Aptychus*. The vertebrata are not well represented. Teeth of *Oxyrhina*, *Lamna*, and *Corax* occur, but *Ptychodus* is rare; vertebræ of sharks are occasionally met with. Many of the above-mentioned fossils were obtained by the Members at this and other pits during the excursion.

After about five minutes' walk the next pit was reached, and the party were kindly met by the proprietor, Mr. Wilfrid Tolhurst, who conducted the Members to the extensive pits west of the main road, abutting on the old Dover Road. Here the method of working the chalk in this neighbourhood and

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other features of interest were pointed out. A vote of thanks to the proprietors of the various pits was accorded, to which Mr. W. Tolhurst responded. The large pits at the south side of Northfleet Church, known locally as the "London Portland" were next visited. Here the tabular layer of flints, which extends over a considerable area, was well seen. The water level in this pit after the excessive drought was only about six inches below the surface. A large number of pebbles have been obtained from this pit, and at about forty feet from the ground, nearly half a bushel were found some few years ago ; unfortunately, none were preserved.

Time did not permit of a visit to Messrs. Bevan and Co.'s pit, but the party walked to a spot where a good view of the pit could be obtained. Immediately in front flowed the Fleet, through a bed of Alluvium, while to the south-west, just before entering the pit, the tramway is made through a very interesting section of brick-earth, from which Mr. F. Spurrell and others have obtained large quantities of mammalian remains. The pits lie to the west of this cutting and are capped in one place by a thin layer of Tertiary beds, and in another by the Swanscombe gravels. A large number of very fine palæolithic implements have been obtained from the gravels capping the chalk, and from the "pipes" in this pit.

After tea, a vote of thanks to the Director and Mr. A. E. Salter was proposed by Mr. Potter and carried unanimously. The return journey was made from Northfleet at 7.30 p.m.

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ORDINARY MEETING.

FRIDAY, JULY 1ST, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

The following were elected members of the Association :—
David L. Luck and Alfred William Oke, B.A., LL.M.

A paper entitled, "A Sketch of the Geology of the Birmingham District, with Special Reference to the Long Excursion of 1898," by Professor C. Lapworth, LL.D., F.R.S., F.G.S., with contributions by Professor W. W. Watts, M.A., Sec. G.S., and W. J. Harrison, F.G.S., was then read by Professor Lapworth, after which Professor Watts exhibited and explained a series of lantern slides illustrative of the district.

Mr. W. F. Gwinnell, F.G.S., exhibited a collection of fossils from the Wenlock Limestone of Dudley.

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EDITED BY

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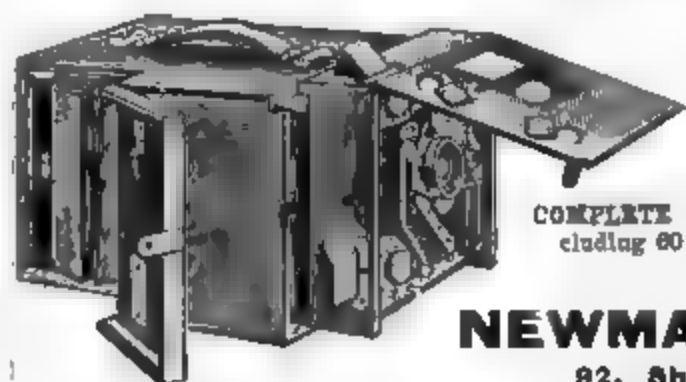
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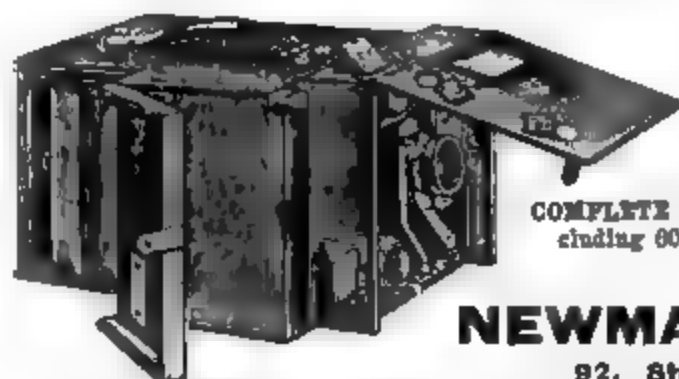
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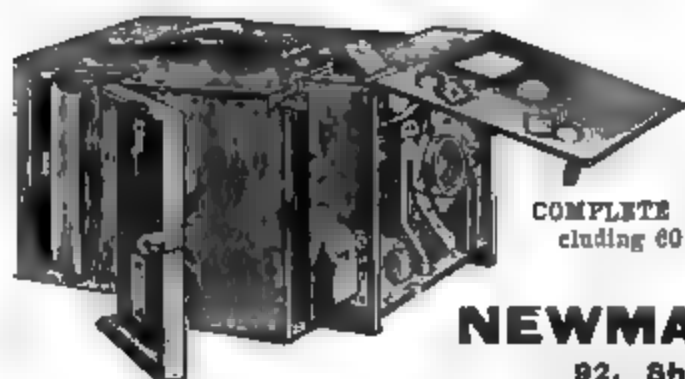
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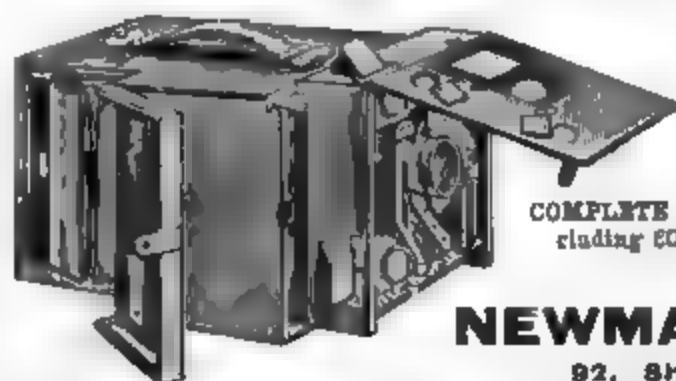
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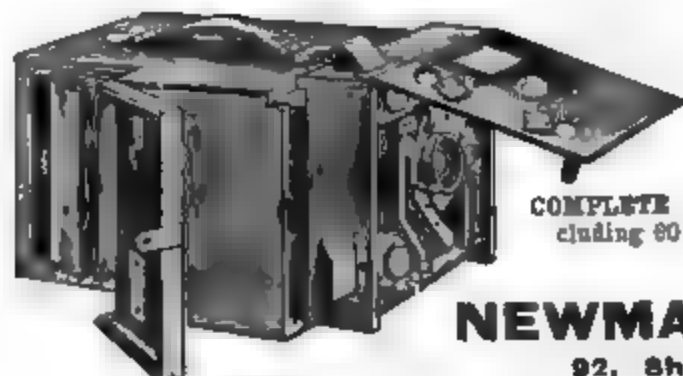
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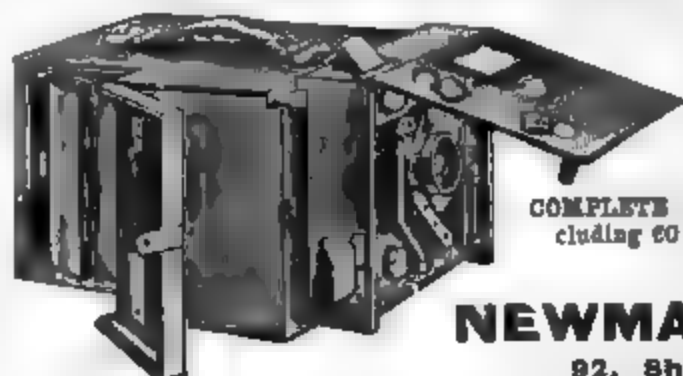
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